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Comparative Response of Cabbage to Irrigation in Southern Malawi

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Abstract

An experiment was conducted at Kasinthula and Masenjere in Chikwawa district in Malawi in the dry seasons (May through August) of 2006 and 2007 to evaluate yield response of cabbage (Brassica oleraceae) to irrigation frequency. The study was laid out in a randomized complete block design (RCBD) where three irrigation frequencies served as treatments: F1-Irrigated twice a week, F2-Irrigated once a week and F3-Irrigated once a fortnight. At Kasinthula, weight of marketable heads and water-use efficiency (WUE) were significantly different ($P<0.05$) across the irrigation frequencies. At Kasinthula and Masenjere, F1 resulted in highest yield of 32.9 and 23.0 t ha^{-1} in 2006 and 2007 seasons. There was a 50% and 25% reduction in yield in 2007 at Kasinthula and Masenjere Research sites. WUE peaked in F1 to 83.6 and 57.5 kg ha^{-1} mm^{-1} in 2006 and 2007 while lowest values were noted using F3 resulting in WUE of 57.9 and 39.4 kg ha^{-1} mm^{-1}. Water productivity (WP) was significantly different across irrigation frequency ($P<0.05$). F3 resulted in the highest WP of 11.8 and 7.4 kg m^{-3} in 2006 and 2007, respectively. The lowest WP of 6.7 and 5.2 kg m^{-3} were observed in F1 in the two years. Comparing all the irrigation frequencies, F3 turns out to be the most effective water saving irrigation frequency suggesting that in the face of competing water needs and dwindling water resources, the longer duration F3 irrigation frequency is preferred to shorter duration ones. Where water is considered ample, F1 is recommended.

Keywords: irrigation frequency, furrow irrigation, water productivity, water-use efficiency

1. Introduction

Vegetables are an important source of vitamins and mineral which are vital for good health. Despite being widely grown in Malawi, adequate supplies of vegetables are mostly available in the rainy season (November through April) yearly. Consequently, supplies are not adequate throughout the year especially in semi-arid areas of the country. By increasing water productivity in vegetable production, irrigated agriculture may increase substantially (FAO, 2000; Rockstrom et al., 2002). Smith (2000) reported that genetic characteristics of a crop are the primary factors determining water use productivity because they determine assimilation characteristics, the respiration and physiological processes that convert the assimilates into biomass and harvest index which partitions biomass into the harvestable product and non-useful product. Doorenbos and Kassam (1979) categorized crops according to their yield response to water namely: crops sensitive to water stress and those tolerant to drought. They observed that the crops are self-exclusive, meaning that high producing crops which can obtain high water productivity are highly sensitive to water stress, while stress tolerant crops can still achieve yields under water stress but do not attain the high yield and water use under optimal water supply, ceteris paribus.

The amount of water required by plants and the timing of irrigation are governed by prevailing climatic conditions, crop and stage of growth, soil moisture holding capacity and the extent of root development as determined by crop type, stage of growth and soil. Thus, the amount of water required by plants varies from place to place. For practical purposes, it is important to determine the relationship between yield and water in a given locality in a simplified form because the relationship is intrinsically complex (Doorenbos & Kassam, 1979) as it is affected by factors other than water such as crop variety, salinity, pests and diseases, and agronomic practices. Better irrigation management after determination of yield response could help in maximizing WUE and avoiding long-term build-up of salinity and soil degradation (Hess & Molatakgosi, 2009). Also, improved water management would help in coping with increasing demands for water by industrial and urban users and the agricultural sector (de Fraiture & Wichelns, 2010) thereby making water available for environmental and other uses (de Fraiture et al., 2010). De Fraiture et al. (2010) advocate for a fresh look at approaches that combine different elements such as the importance of adapting irrigation to new needs, enhancing water productivity, and promoting the use of low-quality water in agriculture. Several researchers observe that there are sufficient land and water resources available to satisfy global food demands during the next 50 years, but only if water is managed more effectively in agriculture.

In Malawi, no study has been conducted recently on vegetables such as cabbage to ascertain the crop's response to various irrigation regimes. It is important that on-farm and/or on-station water management studies are conducted on vegetables under various irrigation schedules and frequencies to determine water use patterns and yields for efficient irrigation management. This explains the need for irrigated vegetable production to meet both subsistence needs of farmers and their commercial objectives. Also, through schedules developed in the studies, it will be possible to provide resource-poor farmers in semi-arid areas of Malawi with options for supplementary irrigation in summer (rainy season) and full irrigation in winter (dry season). Improved irrigation management appears to be the panacea to increased cabbage availability and production in Malawi.

The experiment was conducted to evaluate yield, water-use efficiency and productivity of cabbage under three irrigation frequencies. It was hypothesized that irrigation frequency does not have any significant impact on cabbage yield, water-use efficiency and water productivity.

2. Method

2.1 Study Sites

The experiment was conducted at Kasinthula and Masenjere in Chikwawa District in southern Malawi. Kasinthula lies at 16°S 34° 5′E at 60 m above sea level (a.s.l.) (Fandika et al., 2007) while Masenjere is located at 16°20'S, 35°6'E, approximately 93 a.s.l (Poynton, 1995). The soil at Kasinthula Research Station is Kapasule series, provisionally classified as aquic Hapslustalf (Barak, 1986) in the order Alfisols. The surface horizon is loamy sand while the subsurface horizon is sandy clay loam. It is moderately coarse to moderately fine textured developed in the brown sediments of the lower Shire terrace. The soil is moderately drained with a water table at 2.5 m from the ground surface. The available was estimated to be 100 mm m^{-1} (Chilimba, 1990). Soil physical and chemical characteristics for Kasinthula and Masenjere are presented in Table 1.

The average climatic conditions of Kasinthula Experiment Research Station monthly total rainfall (mm), average maximum and minimum temperature (°C), relative humidity (%), wind speed (km hr^{-1}), sunshine hours (h d^{-1}), solar radiation (Langley), and monthly total evaporation (mm) are presented in Table 2 below. Masenjere research site receives average annual rainfall of 860 mm. The soil is a deep, colluvial sandy loam (Poynton, 1995).

Table 1. Average soil characteristics at Kasinthula and Masenjere

Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class	FC (%)	PWP (%)	Available water (%)	Bulk density (g/cm^3)	pH (water)	N (mg/kg)	P (mg/kg)
						Kasinthula					
0-30	75	7	18	LS	10.27	5.65	4.62	1.67	6.44	6.0	24
30-60	74	7	19	LS	12.34	5.98	6.4	1.71	6.66	6.0	25
60-90	74	6	20	SCL	13.75	6.69	7.06	1.69	6.57	5.0	25
						Masenjere					
0-30	70	6	24	SCL	ND	ND	ND	ND	6.98	1.0	10
30-60	76	10	16	SL	ND	ND	ND	ND	7.03	1.0	13
60-90	80	8	12	SL	ND	ND	ND	ND	7.02	3.0	16

Notes: FC-Field capacity moisture content, PWP-Permanent wilting point, ND-Not determined.

Table 2. Meteorological data during the dry seasons at Kasinthula in 2006 and 2007

Weather variable	2006					
	May	June	July	August	September	October
Average maximum temperature (^oC)	33.4	29.2	28.9	29.7	33.6	35.3
Average minimum temperature (^oC)	18.3	15.0	12.7	17.5	21.5	22.0
Average relative humidity (%)	64.0	68.2	71.3	64.0	57.4	78.4
Average wind speed (km h^{-1})	3.7	3.4	2.2	2.9	5.9	4.6
Average sunshine hours d^{-1}	7.8	7.7	7.7	9.7	9.0	9.1
Total rainfall, mm	0.2	0.3	0.0	0.0	0.0	0.0
Average solar radiation (Langley)	476.0	453.0	474.0	512.0	537.0	573.0
Average pan evaporation (mm d^{-1})	4.6	4.3	4.7	6.4	7.9	9.7
	2007					
Average maximum temperature (^oC)	30	26.5	22	31.9	34.7	35.6
Average minimum temperature (^oC)	17	14.1	13	13.3	15.6	19.8
Average relative humidity (%)	81	91	71	89.6	92.2	72
Average wind speed (km h^{-1})	7	8.9	11	11.9	16.1	19.2
Average sunshine hours d^{-1}	8	8.5	8	8.9	9.7	9.9
Total rainfall, mm	4.9	5.1	45.2	6.4	0	14
Average solar radiation (Langley)	-	-	-	-	-	-
Average pan evaporation (mm d^{-1})	4.9	5	3.8	5.4	7.2	8.9

2.2 Experimental Design and Treatments

Irrigation frequencies constituted the treatments in the study namely: F1-Irrigated twice a week, F2-Irrigated once a week, and F3-Irrigated once bi-weekly. All treatments were replicated four times, in plots 5 m by 5 m, where 1 m was left on each side as a buffer for gravimetric soil moisture determination and routine measurements. Plants, cabbage variety Giant drumhead, were planted at 0.6 m in between and within rows.

2.3 Fertilizer and Water Application

Calcium Ammonium Nitrate (CAN), an inorganic fertilizer was applied at the rate of 100 kg N ha^{-1} by banding. Irrigation water was applied in 5-m long furrows using a gated 10-cm diameter PVC pipe. Each gate was set at a flow rate of 30 litres per minute. The flow rate out of each gate was determined using a calibrated bucket. The PVC pipe was laid at the beginning of the furrows, and connected to a concrete lined canal in which water level was maintained at a constant head above the center of the PVC pipe inlet.

2.4 Irrigation Scheduling

The experimental plots were irrigated to field capacity at planting and irrigation schedules were imposed four weeks after planting. The soil moisture storage was estimated from available water holding capacity of 100 mm m^{-1} and the crop root zone. The crop consumptive use was computed from climatic data using the evaporation pan method for estimating reference evapotranspiration (ETo). The ETo was calculated daily and then multiplied by the cabbage crop coefficient (Kc) (Table 3) at a particular growth stage to determine the consumptive water use based on well established procedures (Doorenbos & Pruitt, 1977; Doorenbos & Kassam, 1979; 1986; Allen et al., 1998), according to the following equation:

$$ETC = Kc * ETo \quad (1)$$

Where ETc is crop consumptive water use (mm).

The equation for estimating crop WUE (kg ha^{-1} mm^{-1}) according to Kirda (2002) and Lovelli et al. (2007) is:

$$WUE = \frac{Y}{ETa} \quad (3)$$

Where Y is crop yield (kg ha^{-1}) and ETa is actual evapotranspiration (mm) which was regarded as crop evapotranspiration (mm), in this study.

Water productivity (WP in kg m^{-3}) according to Smith (2000) is given by the following expression:

$$WP = \frac{Y}{TWA} \quad (3)$$

Where TWA is total water applied (mm).

Table 3. Crop coefficients (Kc) for cabbage at various growth stages

Growth stage	Crop coefficient, Kc	Days after planting (DAP)
Initial stage	0.45	1
Crop development stage	0.75	22
Mid-season stage	1.05	48
Late season stage	0.9	118

2.5 Statistics

All the data were analyzed in GENSTAT 6.0 and means were separated using the Fisher's Least Significant difference (LSD) method.

3. Results and Discussion

3.1 Cabbage Yield at Kasinthula and Masenjere

Irrigation frequency significantly influenced weight of marketable heads at both sites ($P<0.05$). At Kasinthula (KAS) and Masenjere (MAS), F1 resulted in highest yield of 32.9 and 23.0 t ha^{-1} in 2006 and 2007 seasons (Figure 1). There was a 50% and 25% reduction in yield in 2007 at Kasinthula and Masenjere research sites. In both years, yields were four to five times higher at Masenjere than Kasinthula. Also, number of marketable heads at Masenjere was two to three times higher compared with that of Kasinthula. The results show that the Giant Drumhead variety of cabbage favours Masenjere and may not be suitable for Kasinthula.

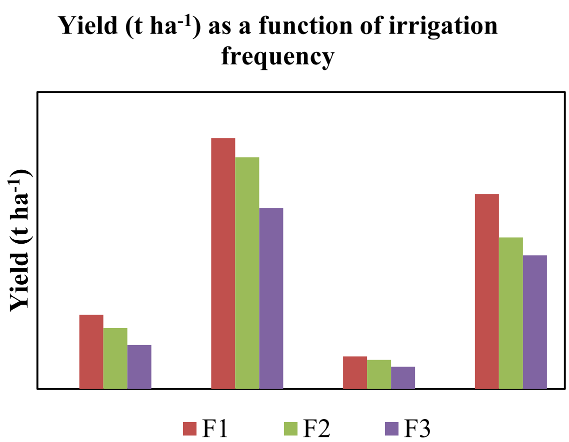

Figure 1. Yield (t ha^{-1}) as a function of irrigation frequency

However, there were no significant differences in yields and number of marketable heads at Masenjere in both years between the three irrigation frequencies (Figure 2). This suggests that farmers faced with dwindling water resources farmers could opt for irrigation frequency F3 where 202 mm of water was applied to cabbage. Approximately 508 and 306 mm of water were applied in irrigation frequencies F1 and F2. F3 offers the growers a rational basis realizing reasonable yield while saving water. Where a farmer has ample water resources for the entire season, the F3 would still be employed but with adjustments on the amounts of water to be applied per season. F3 present an opportunity for introducing deficit irrigation in cabbage at Kasinthula and Masenjere. It was noted that average cabbage evapotranspiration for Kasinthula and Masenjere was 393 mm and was exceeded by F1 and F2. F3 did not meet the cabbage water requirement.

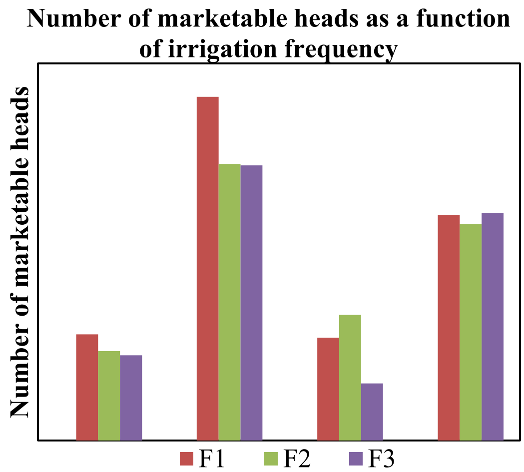

Figure 2. Number of marketable heads as function of irrigation frequency

The results agree with the findings of several researchers (Kleinhenz & Radovich, 2003; Radovich, 2004; Radovich et al., 2004) who documented the effect of irrigation timing on head development and weights on cabbage. They concluded that head size and weight were greatest in cabbage receiving irrigation during head development. In their studies, the independent and interactive effects of year and irrigation treatment were largely explained by the proportion of crop evapotranspiration replaced during head development. The yields obtained in Masenjere are similar to those reported by Imtiyaz et al. (2000) in field studies in Botswana where cabbage yielded as high as 71.65 t ha^{-1}. The cabbage yields at Kasinthula, despite receiving similar irrigation management treatments, suggest that the variety Giant drumhead is not suitable for the area.

3.2 Water Use Efficiency (WUE) and Productivity (WP) of Cabbage

WUE was significantly different across irrigation frequencies ($P<0.05$) at Kasinthula only in both years (Table 3). WUE peaked in F1 to 83.6 and 57.5 kg ha^{-1} mm^{-1} in 2006 and 2007 while lowest values were noted using F3 resulting in WUE of 57.9 and 39.4 kg ha^{-1} mm^{-1}. WUEs at Masenjere were four to five times those obtained at Kasinthula research site probably due to high evaporative demand at Kasinthula compared with Masenjere site (Barak, 1986).

Table 3. Effects of irrigation frequency on water-use efficiency (kg ha^{-1} mm^{-1})

¶Irrigation frequency	2006		2007	
	Kasinthula	Masenjere	Kasinthula	Masenjere
F1	38.1a	129.1a	16.4	98.6
F2	31.3b	119.0a	14.7	76.6
F3	22.7c	93.1b	11.2	67.5
‡$LSD_{0.05}$	4.7	15.0	4.6	13.9
†CV (%)	17.3	14.8	15	12.8
§Significance	*	NS	*	NS

¶F1-Irrigated twice a week, F2—Irrigated once a week and F3-Irrigated once a fortnight.

‡Least significant difference at α=0.05.

†Coefficient of variation.

§NS, * *mean not significant and significant at* α=0.05.

Water productivity was significantly different across irrigation frequency ($P<0.05$). F_3 resulted in the highest WP of 11.8 and 7.4 kg m^{-3} in 2006 and 2007, respectively. The lowest WP of 6.7 and 5.2 kg m^{-3} were observed in F_1 in the two years. The results on WP show when faced with competing water needs in irrigated crop production then longer irrigation schedules are preferable. Our results on WP in vegetables agree with those obtained by Pachpute (2010) who reported water productivity of 12.1 kg m^{-3} in cucumber using pitcher irrigation and water conserving technologies such as manure application and mulching in neighboring Tanzania. The WP values also fall within the ranges reported by Molden et al. (2010) for vegetable crops. Comparing all the irrigation frequencies, F_3 turns out to be the most effective water saving irrigation frequency suggesting that in the face of competing water needs and dwindling water resources, the longer duration F_3 irrigation frequency is preferred to shorter duration ones.

Table 4. Effects of irrigation frequency on water productivity (kg m^{-3})

¶Irrigation frequency	2006		2007	
	Kasinthula	Masenjere	Kasinthula	Masenjere
F1	3.4b	10.0a	3.2	7.2
F2	3.7ab	13.8b	5.2	8.9
F3	4.4a	18.1c	2.9	11.8
‡$LSD_{0.05}$	1	3	2.5	4.3
†CV (%)	30.2	21	13.3	21.1
§Significance	NS	*	NS	*

¶F1-Irrigated twice a week, F2—Irrigated once a week and F3-Irrigated once a fortnight.

‡Least significant difference at α=0.05.

†Coefficient of variation.

§NS, * *mean not significant and significant at* α=0.05.

4. Conclusion

The study sought to determine the effect of irrigation frequency on WUE, WP and yield of cabbage. As confirmed in the results, we conclude that irrigation frequency has a significant bearing on yield, WUE and WP of cabbage. We also note that research site resulted in remarkable differences in the crop response functions under study. Thus, we suggest further investigations using several cabbage varieties at both Kasinthula and Masenjere research sites before passing on the recommendations to farmers in order to obtain more consistent results. However, some clear trends were observed. First, F1 resulted in highest yield and WUE in both seasons while F3 yielded lowest. The reverse was true for WP. Comparing all the irrigation frequencies, F3 turns out to be the most effective water saving irrigation frequency suggesting that in the face of competing water needs and dwindling water resources, the longer duration F3 irrigation frequency is preferred to the shorter duration ones. Where water is considered ample, F1 is recommended. Resources permitting, a research attempt on raising cabbage under both controlled greenhouse and field conditions should be made because field studies alone consistently showed low cabbage yields at Kasinthula despite good irrigation management.

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