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Effect of Different Interval and Water Requiring Growth Time of Leek (*Allium ampeloprasum Var. Porrum* L) for White Shaft Yield and Yield Components at Wolaita Zone, Ethiopia

Birhanu Lencha[1], Belay Yebo[1] and Tesfaye Dejene[2*]

[1]*Wolaita Sodo University, College of Agriculture, p. box 138, Sodo, Ethiopia*
[2]*Areka Agricultural Research Centre, p. box 79, Areka, (SARI) Southern Ethiopia*

**Corresponding author*

Abstract

Leek is grown for its thickened cylindrical white and green shaft made up of long leaf bases. The increasing scarcity and competition for irrigation water entails adoption of innovative practices that increase the efficiency of water use. Deficit irrigation provides a means of reducing water consumption while minimizing adverse effects on yield. An experiment was conducted to determine the effects of different level of deficit irrigation treatments compulsory at different active growth periods on the shafts yield of leek (var. Leek variety, namely Kenton) and thereby to identify the critical active growth period of leek for water supply at Gedala-Himbecho in the 2019 and 2020 growing season. The treatment consisted of application of 20, 40, 60 and 80% of the crop water requirement at the early, vegetative, Shafting and maturity periods and application of 20 and 40% of ETc at two consecutive active growth periods of the variety used. The treatments were arranged in RCBD and were replicated three times. Relevant data on soil, amount of irrigation water applied, weather and crop were collected and analyzed. The results showed that application of 20, 40 and 60% of the total water requirement of the crop at shafting period significantly ($P<0.05$) hastened maturity by 9, 7 and 4 days, respectively as compared to the control treatment. The highest total white shaft yield was obtained from the control treatment followed by application of 40% ET_C at shafting plus maturity periods while the lowest total white shaft yield was recorded under the application of 20% ET_C at Veg. plus shafting periods. The periods irrigated with 20% ET_C and the vegetative growth and shafting periods irrigated with 40% ET_C were found to be more susceptible to deficit irrigation than application of 20, 40 and 60% ET_C at the other active growth periods. None of the deficit irrigation treatment significantly improved the irrigation water use efficiency of Leek variety, namely Kenton. In order to avoid high yield reduction, this variety should not be stressed at shafting periods and consecutively at any of its growth periods. Under conditions of water shortage, however, the best periods to maximize water saving on irrigation of Leek variety, namely Kenton without a yield reduction of above 31% is application of 40% of its water requirement during the shafting and maturity periods. It is recommended to repeat the experiment for multi-location and different season to confirm the current results.

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Keywords

Leek variety, Active growth period, Shaft yield, Total yield

Introduction

Leek *(Allium ampeloprasum* L.) is a vegetable that has been cultivated from the earliest times. It is not naturally found in the wild, but it is considered to have originated from wild forms of *A. ampeloprasum,* a species which originates from the Near East (Jones 1991).The leek belongs to the genus *Allium* of the family *Alliaceae* (Hanelt, 1990). Leek has been known since Linnaeus as *Allium porrum* L, but nowadays some taxonomists prefer a broader species concept and place leek in the large *Allium ampeloprasum* complex. It is a biennial plant and its reproductive system is predominantly cross-fertilization although self fertilization is possible (Meer and Hanely, 1990). Leek is a slow growing monocotyledonous species of the genus; it is characterized by broad, flat, tightly wrapped, dark green leaves, a long, thick white stalk, and a slightly (to some extent) bulbous end (Filjushin, *et, al* 2011). It is very tolerant to cold weather, although the optimum temperature for vegetative growth is around 20 °C. The leaves and long white blanched stem are eaten cooked or can be added to salads (Theunissen and Schelling, 1998).

Leek is predominantly a European crop with significant cultivation in Turkey (9000 ha), France (5800 ha), Belgium (4800 ha) and Poland (4400 ha). Although worldwide, Indonesia is the largest producer of leek as stated by FAO (2002). In Belgium, leek is one of the most important vegetables cultivated outdoors accounting for 16% of the total field agricultural production value (Fattorusso *et al.*, 2001). It is grown for its cylindrical pseudo stem, which is blanched white from growing underground and is made up of long leaf bases. The white shaft is used in many culinary preparations, whereas the green leaves are considered inferior and are, therefore, usually only used in soups or discarded during harvesting and processing of the fresh produce for the market. Leek is grown in Ethiopia has a great potential but there is no statistical data in Ethiopia and there is infant stage to produce leek, the possible production throughout the year both for local consumption

In Ethiopia, the leek production is found in the Eastern Harareghe; southern part especially awassa area and Areka Wolaita zone of Ethiopia (Birhanu *et al.,* 2016). In these areas, where vegetable production is widely cultivated as cash crop by small-scale, private and large-scale farmers, rainfall is unreliable and insufficient to support leek production. There are two rainfall season 23% in the Eastern Harareghe, southern part especially awassa area and wolaita zone. There was limited growth between November and February, followed by rapid growth, being highly uneven and erratic in its distribution and undependable pattern for economic farming and have long rain season, being more dependable for agricultural farming. Therefore, to offset this deficit during dry season and maintain a high crop and vegetable yield in this area irrigation is indispensable practice (Salisbury and Ross, 1992).

Irrigation is one of the vital inputs for the production of vegetables in many parts of Ethiopia. In the southern part, farmers prefer to produce leek under irrigation during the dry period (October-April) due to high domestic and export markets in fresh and processed forms, its yield per unit area, availability of suitable cultivable variety, and ease of propagation by seed and lower incidence of diseases. The irrigated land under vegetables and other irrigated crops by state and private farms is expected to increase from 45,000 to 130,000 ha in the short term and to 210,000 ha in the medium term (MOWR, 2007). As a result the, demand for irrigation water in the Eastern Harareghe, southern part especially awassa area and Sidama zone is going to increase (Birhanu *et al.,* 2016). Moreover, inefficient utilization of irrigation water is an obstacle to vegetable production in all irrigation schemes. Scarcity and growing competition for fresh water resources will also reduce its availability during all crop growth periods particularly at critical growth stages of the crops; which adversely affect crop growth and yield. This situation limits the expansion of vegetable farms and the possibility of extending production throughout the year. The production and productivity of leek is not as such expected because of lack of appropriate planting space and ideal variety for the specific areas. It is possible to ration water applications on a highly selective basis at particular phenological periods with negligible losses in terms of quantity and quality of yield. Therefore, a better understanding of the moisture requirement of leek and evaluation of its vital water needful active growth period is needed in order to develop a proper deficit irrigation scheduling (Awkee *et al.,* 2008).

There was no any study have not been carried on regulated deficit irrigation scheduling for leek in Ethiopia based on growth periods. While found that the third growth periods/shafting was the most critical period for leek irrigation, there were no detailed studies carried out in the evaluation of the crucial periods of leek for better scheduling deficit irrigation to maximize pseudo stem (shaft) production and saving irrigation water in the wolaita zone. Therefore, the objectives of this study were:

To determine the effects of different rate of water supply at different growth period on the shafting yield.

To evaluate the water requirement at active growth period of leek for yield and water use efficiency of leek.

Materials and Methods

Description of the study area

A field study was conducted at Gedala-Himbecho, Wolaita zone, located 18 km North West of Areka Agricultural Research Center with altitude of 1680 meters above sea level, 7^{o} 69' N latitude and 37^{o} 47' E. longitude. The site is situated in the SH2 major agro-ecological, which is tepid to cool-sub humid mid highlands. The average (year 2006-2011) annual rain fall of the study area was 1520 mm and the total annual rain fall for the cropping season of 2019 was 1598 mm, which occurs in two seasons in the year. The large number of different leek cultivars makes it possible to sow the crop from December to June and to harvest from June to May. The average maximum and minimum temperature of Gadala Hembecho area are 25.4 and $13.4o^{C}$, respectively. The site was selected for the availability of irrigation facility.

Experimental treatments and plant material

The experiment consisted of four water regimes (20, 40, 60 and 80% of crop water requirement, ET_C) imposed at four active growth periods of leek (initial, vegetative, shafting and maturity) and application of 20 and 40% ET_C at two successive crop development periods with seed of the leek, variety namely Kenton is an European cultivar which can be grown in different parts of country including study area for root production but not for seed production.

Data to be collected

Shaft diameter and white shaft length were measured in cm from five randomly selected plants collected for dry matter determination using ruler and caliper, respectively at every growth periods. Shaft yield and biomass were determined in kg/ha by harvesting plants from the net plot area of 1 m^2 and then weighed using a sensitive balance. Marketable and non-marketable white shafts were also graded based on diameter size into small, medium, and large (20-35, 35-50, >50 mm, respectively). Injured and small shafts of less than 20 mm diameter were recorded separately. Total Yield (t ha^{-1}):- total sum of marketable and unmarketable shaft yield of plants measured and the yields obtained from plots were converted to hectare base. Total white shaft length at maturity (t ha^{-1}): - it was recorded from fresh ripe lower up to green part selected from the sample plants taken and converted in to hectare basis Harvest index:- was calculated as the ratio of yield to the total above ground biomass. Water use efficiency:- was determined by dividing the shaft yield produced from each treatment to the total water applied for the respective treatments.

Statistical analysis

All collected data were subjected to analysis of variance (ANOVA) of RCBD in factorial arrangements using SAS software (SAS, 2002) version 9.1. All significant mean separation was compared using Least Significant Difference (LSD) test at 5% probability level.

Results and Discussions

Amount of irrigation water applied to each treatment

Data collected on the effect of different levels of irrigation treatments on growth, yield and yield components of leek grown for shaft white and green part production were analyzed, interpreted and presented in the different sections below. Leeks can be grown on a wide range of soil types, but the most suitable are sandy loam to sandy clay loam, silts and high organic matter peat based soils. Leeks have a very high requirement for water (Birhanu *et, al* 2016). The amount of irrigation water applied in the different treatments during the experimental period is shown in Table 1. The total amount of irrigation water applied varied from 221.7 to 464.4 mm without including water applied during establishment period (26.6 mm). The highest amount of water was applied to the control treatment which is 80% of the water requirement of the crop while the lowest was applied to plants which received 20% of their water requirement at vegetative and shafting periods.

Effects of water deficit on yield and yield components

White shaft diameter and length

The water regimes did not significantly affect white shaft length and diameter at the end of the shafting period but affected the parameters significantly at shaft maturity

(Appendix Table 1). Application of 20% of ETc at V+S periods and at S period, application of 40 ETc at V+S periods and application of 60% ETc at the I period resulted in significantly lower white shaft length as compared to the control and the rest of the treatments. On the other hand, the white shaft length of plants grown under 20% ETc at V and I+V periods, 40% ETc at I, M, I+V and S+M periods, and 60% ETc at V and S periods was not significantly affected by the water regime treatments as compared to the control (Table 2). The results suggest the detrimental effect of application of 20 and 40% of crop water requirement at shafting and consecutively at vegetative and shafting periods in reducing the shaft length of leek.

Application of 20% ETc at vegetative+ shafting, shaft and vegetative+ shafting periods resulted in significantly lower shaft diameter than the rest of the treatments which did not significantly reduce the parameter from the control (Table 2). The results on white and green shaft length and diameter indicate the sensitivity of shaft length at wider soil water levels and active growth white shaft compared to shaft or white diameter which is affected by lower soil water at selective active growth white shaft of leek. Insufficient irrigation reduces total yield by reducing the bulb size. In previous studies, yield reductions were associated with reduction of white shaft diameter; length and shaft/pseudo stem weight (Doorenbos and Kassam, 1979; Kadayifci *et al.,* 2004, Martin *et al*., 2004). Stressed onion plants may white shaft too early, produce small-sized white and leave shaft splits and, thus, produce reduced marketable yield (Aweke Nigatu *et al*., 2008.)

White shaft and green leaves yield

The water regime treatments significantly affected the marketable, non-marketable and total white shaft and green leaves yields. The highest marketable yield was recorded in the control treatment while the lowest was recorded in the treatments which involved application of 20 and 40% ETc at vegetative +shaft periods and 20% at shafting periods (Table 3). The control treatment gave the highest non-marketable yield whereas the lowest was recorded in plants irrigated with 20% of ETc at veg and E+V active growth periods (Table 3). The rest of the treatments produced similar amount of non-marketable yield. The control treatment gave the highest total shaft yield followed by application of 40% ETc at shafting and maturity periods (Table 3). The lowest total shaft yield was recorded under the application of 25% ETc at vegetative shafting periods followed by the same deficit application at shafting, early+veg, shafting, maturity periods and application of 40% ETc at the vegetative and shafting periods (Table 3).

According to the relative total yield reduction data shown in Table 3, all periods except the initial period under the 20% ETc significantly reduced shaft yield from the control. Less than 40% yield reductions were observed when plants were irrigated with 40 and 60% of their water requirement at early, vegetative, shafting and maturity active growth period. Application of 60% of ETc at each active growth periods did not improve shaft yield over application of 40% ETc at the same active growth periods (Table 3). Therefore, for economical use of water, it is better to irrigate Kenton variety either with 20% of its ETc during the initial period or application of 40% of its ETc at vegetative period. However, the best period to maximize water saving on irrigation of Kenton variety without a yield reduction of above 31% is application of 40% of its water requirement during the shafting and maturity periods (Table 3). Mean total shaft yield, marketable and non-marketable of leek grown for shaft production as influenced by irrigation water regimes at different active growth period at Gedala-Himbecho in 2019.

The current results observed under the 20% ETc application are in line with previous reports that indicated reduction of leek yield due to water deficit imposed at different active growth periods (Kirda, 2002; Birhanu *et al*., 2016; Pelter *et al*., 2004). For optimum yield, it is necessary to prevent the crop from experiencing water deficit, especially during the bulbing stage. The crop appears to be less sensitive to water deficit during the early initial periods although excessive irrigation during this period can lead to a delayed start of bulbing and a reduced bulb development (Doorenbos and Kassam, 1979).

In a previous study, water deficit of 50-75% during the total growing season at the yield formation period caused a large decrease in bulb yield (Kadayifci *et al*., 2004). These authors, therefore, suggested full irrigation water supply during shafting to achieve large (white shaft/green leaves) and high white shaft weight. Although frequent irrigation enhances yield of leek by providing favorable water balance in its shallow and limited root zone, it is possible to save water by applying less amount of water than required by the crop during the initial and vegetative periods during the time of water shortage as observed in the current study and reported by others (Neefs and Meulemeester, 2010). High yield from frequent irrigation results mainly from an increased shaft weight and slightly from an increase in pseudo stem (shaft) number per plant (Tsouvaltzis *et al.*, 2010).

As observed in the current study under the application of 20% of ETc, water stressed leek plants shaft(white and green) too early, produce small-sized pseudo stems, splits and, thus, produce reduced marketable yields (Lava, 2012)

Total biomass at harvest

Total biomass at harvest was significantly affected by the water regime treatments (Appendix Table 2). All the deficit irrigation treatments significantly reduced the dry matter at harvest from the control. However, applications of 20% ETc at V+S and S period and 40% ETc at V+S periods resulted in lowest dry matter at harvest than the rest of the treatments (Table 4). The lower biomass recorded in all the deficit irrigation treatments than the control could be either due to reduced active growth or high partitioning of the top dry matter to the shaft during the late growth. Previous workers reported low biomass of leek under deficit conditions as a result of low leaf area development in the later growth stages (Wouters *et al.*, 2013; Salisbury and Ross, 1992). (Table 4)

Mean Total biomass, harvest index and irrigation water use efficiency of leek grown for pseudo stalks/shaft production as influenced by different irrigation water regimes at Gadal Hembecho (2019).

Table.1 Amount of irrigation water applied in the different irrigation treatments

Water regimes	Total amount of water applied (mm)	
20	1	429.50
	2	356.60
	3	329.50
	4	393.80
	5	321.70
	6	221.70
	7	258.80
40	1	441.10
	2	392.60
	3	374.50
	4	417.30
	5	369.30
	6	302.60
	7	327.40
60	1	452.80
	2	428.50
	3	419.50
	4	440.90
80	5	464.40

$_E$=early period, V=vegetative period, S=shafting period, M=maturity period.

Table.2 Mean shaft (white and green) length and diameter (cm) of leek grown for leek production as influenced by irrigation water managements at different active growth periods at Gedala-Himbecho

Water regime (%)	Application period	SLS	SLM*	SDS	SDM
20	Early	6.33	4.21cd	4.57	5.45abc
	Vegetative	7.05	4.87ab	5.16	5.32abc
	Shafting	6.89	3.85de	4.69	5.90cd
	Maturity	7.30	4.27bcd	5.22	5.97a
	Early + Veg.	7.17	4.49abc	4.93	5.24abc
	Veg.+ Shafting	6.90	3.47e	4.63	4.19d
	Shafting+ Maturity	7.09	4.36bcd	4.64	4.04bcd
40	Early	7.15	4.49abc	5.21	5.95a
	Vegetative	7.15	4.17cd	4.60	5.17abc
	Shafting	7.26	4.04cdf	4.93	5.41abc
	Maturity	7.20	4.60abc	5.5	5.12abc
	Early + Veg.	7.17	4.48abc	5.09	5.24abc
	Veg.+ Shafting	7.29	3.79de	5.34	5.17abc
	Shafting+ Maturity	7.15	4.66abc	5.09	5.41abc
60	Early	7.33	3.83de	5.07	5.94ab
	Vegetative	7.05	4.51abc	4.95	5.42abc
	Shafting	6.84	4.49abc	4.38	5.21abc
	Maturity	7.26	4.14cd	4.92	5.12abc
80	Shafting+ Maturity	7.97	5.10a	5.19	5.95a
LSD (P<0.05)		Ns	0.63	ns	0.74
CV%		9.45	8.78	14.23	12.35

E= Early, V= vegetative, S= shafting periods, M= maturity, E+V= early and vegetative, V+S= vegetative and shafting, S+M= shafting and maturity. WSLV= white shaft length at vegetative period, WSLS= white shaft length,, WSLM= white shaft length at maturity periods; WSDS = white shaft diameter at shafting; WSDM = white shaft diameter at maturity.
*[2]Means followed by the same letter case in a column are not significantly different from each other at 5% P level.

Harvest index

Analysis of variance indicated that harvest index was significantly ($p<0.05$) influenced by the water regimes treatments. Half of the treatments had similar HI to that of the control treatments. However, the lowest HI was recorded under the application of 20% ETc at early plus vegetative periods and 40% ETc at the early period while the highest was recorded under the application of 20 and 40% ETc at veg plus shafting and shafting maturity periods (Table 4). Since HI is a measure of assimilate partitioning from the vegetative dry mass to the economic yield, it is influenced by the magnitude of the economic yield and the vegetative biomass or both. Investigation of the yield data presented in Table 2 shows that the low HI in the 25% ETc application at Vegetative +Shafting is a result of low shaft yield recorded in the treatment while the one in the 50% ETc at shafting and maturity periods seems to be from both high yield and biomass. Harvest Index considered as a measure of the proportion of assimilates transported to the shaft, and it is a common measure of varietal performance under a set of growing conditions (Kopsell *et al.*, 1999; Lee *et al.*, 2009). The current results on HI are in line with previous reports on leek (De Clercq *et al.*, 2013; Kadayifci *et al.*, 2004; Martin *et al.*, 2004).

Irrigation water use efficiency

Analysis of variance revealed that irrigation water use efficiency was significantly affected by the water regime treatments. Significantly higher irrigation water use efficiency was recorded from the control and application of 20 and 40% ETc at shafting and maturity periods than the rest of the treatments which had similar values (Table 4). In most of the deficit irrigation treatments, the irrigation water use efficiency values were far lower than the control indicating that the amount of the saved water did not compensate for the amount of the yield loss. The current results are not in conformity with the reports of (Kopsell *et al.*, 1999; Lee *et al.*, 2009) who stated that when irrigation water becomes a limiting factor, yield losses due to reduced soil moisture could be compensated for by water use efficiency. In fact, diverting the saved water to increase the irrigated area could compensate for the decrease in crop yields.

Conclusion and Recommendation are as follows

Information on leek water requirement and crop responses under different water application period and water management strategies are very crucial for profitable and sustainable vegetable crop production. In view of this, an experiment was conducted to investigate the effects of different rates of deficit irrigation compulsory at different active growth period on shaft yield and yield components for critical growth period of leek to water deficit at Gadala Hembecho which is located in Wolaita Zone the Southern part of Ethiopia. The treatment consisted of application of 20, 40, 60 and 80% of the crop water requirement at the early, vegetative growth, shafting and maturity periods and application of 25 and 50% of ET_C at two uninterrupted growth periods. The result shows that relative to the control treatment, significantly shorter plants were recorded under the application of 25% ETc at vegetative and shafting periods followed by application of 50% ETc at shafting and actively vegetative growth and shafting period and 25, 50 and 75% of the total water requirement at shafting period, significantly ($P<0.05$) hastened the crop maturity by 10, 6 and 3 days, respectively. Lower dry matter was recorded when 25% of ETc was applied at actively vegetative growth and shafting periods followed by application of the same amount of water at shafting and maturity periods. Except application of 75% ETc at the early period, all treatments reduced LAI as compared to the control. The lowest leaf area index of plants was recorded when plants were irrigated with 25% of their ETc at the early stage and 50% at the vegetative growth and shafting periods.

Therefore, from the result of this research, it can be concluded that under condition of irrigation water scarcity, it is better to irrigate Kenton variety either with 25% of its ETc during the early periods or application of 50% of its ETc at active vegetative growth period. However, the best period to maximize water saving on irrigation of Kenton without a yield reduction of above 31% is application of 50% of its water requirement during the shafting and maturity periods. Since this research is a one year study in a single season and location, further research over locations and years is necessary to check the present results.

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