Verification of the efficiency of alternate furrow irrigation on water productivity and onion yield in Sekota Woreda

*Messay Abera, Aemro Wale, Yalelet Abie, Tilahun Esubalew

Sekota Dry Land Agricultural Research Center, P.O.Box, 62, Sekota, Ethiopia

Corresponding author: Mesay Abera, E-mail: messayabera396@gmail.com

Abstract

The experiment was conducted on 2017/2018 irrigation season in woleh irrigation scheme Sekota woreda. Three irrigation methods, alternating furrow irrigation (AFI), conventional furrow irrigation (CFI) and fixed furrow irrigation were verified on three separate plots. Each irrigation method was using 75% amount of irrigation water for each methods at five days irrigation interval, were verified for irrigated onion. The results shows that total irrigation water applied in the AFI and FFI treatment was roughly half (3038m^3) that applied to the CFI treatment (6078m^3). There was significant reduction in irrigation water used with the AFI but a non-significant reduction on the onion yield production. The AFI water productivity was a stastically significantly difference from FFI and CFI. The water productivity obtained 4.05 kg m^{-3} with AFI and 3.16 kg m^{-3} with FFI which was nearly double the 2.15 kg m^{-3} with CFI. Alternate furrow irrigation (AFI) is gaining interest as a means of saving water while minimizing loss in crop production. Given the potential water savings of AFI, a field experiment was conducted in Sekota woreda at woleh irrigation scheme by growing onion with AFI, conventional furrow irrigation (CFI) and fixed furrow irrigation (FFI) in which every furrow irrigated. While this reduction in yield and/or potential income may appear small, it could be critical to the welfare of individual farmers, who may as a result hesitate to make changes from CFI to AFI. Therefore; it is recommended that areas with insufficient water resource for irrigation in Sekota or agro-climatically similar areas can use 75% of irrigation water at five days irrigation interval in alternate furrow irrigation methods throughout the growing season, for optimum production of irrigated onion.

Key words: Alternate furrow, conventional irrigation, fixed furrow, irrigation amount, yield

Introduction

Onion (*Allium cepa* L.) belongs to the genus Allium of the family Alliaceous which was believed to be originated in southwestern Asia, being the center of domestication and variability, from where it was spread first across the world and has been cultivated for over 4700 years as annuals for bulb production purposes(Brewster, 2008). The onion is recognized as one of the most important vegetable crops that cultivated throughout the world since its introduction to the worlds. It has grown mainly as a food source and used as cousins and value addition for different dishes. In Ethiopia, the consumption of the crop is very important in the food seasoning and in daily stews as well as in different vegetable food preparation uses and also the chemical flavonoids, anthocyanins, fructo-oligosaccharides and organosulphur compounds found in the onion is considered as medicinal and health benefits to fight different diseases including cancer, heart and diabetic diseases(Goldman, 2011).

Onion is one of the most popular vegetables in Ethiopia with a volume of2, 648,493.54 Quintal onion bulbs from 29,517.01ha of lands. Onion is among the largest production and highly commercialized vegetable crops in Amhara region grown under irrigation. Currently farmers in most irrigable areas of the Amhara region produce large amount of onion bulbs every year. For instance, in 2015/16 production year the region have 12,262.79 hectare of land covered by onion crop (*CSA*, *2016*).Efficient water use has become an important issue in recent years because the lack of available water resources in some areas is increasingly becoming a serious problem. During the last two decades, water–saving irrigation techniques such as deficit irrigation (DI) and partial root zonedrying (PRD) or alternative furrow irrigation (AFI) have been developed and tested for field crops and fruit trees. Most recently, these irrigation techniques are being tested also in vegetable crops such as tomatoes(Zegbe-Domınguez *et al.*, 2003). Water use efficiency should be improved by reduced leaf Transpiration .Stomata control the door of plant gas exchange and transpiration water loss. Recent Investigations have shown that stomata may directly respond to the availability of water in the soil such that they may reduce their opening according to the amount of water available in the soil. Alternate furrow irrigation was practiced for a number of crops such as potato, tomato, soybean and corn to conserve water (Shayannejad and Moharreri, 2009, Nasri *et al.*, 2010, Rafiee and Shakarami, 2010, Kashiani *et al.*, 2011). In the study on tomato at Orissa (India), alternate furrow irrigation gave the highest wateruse efficiency (5,140kg ha^{-1}

mm^{-1}) among several furrow treatments. Alternate furrow irrigation can prevent severe leaf water deficit, which develops in the shoots when irrigation is drastically reduced. It is well known that leaf growth and shoot elongation are inhibited when shoot water deficit develops and turgor is reduced as a result.

Globally and more particularly in developing Countries, changing water availability and quality pose complex problem and management options are not easy. The changing situation comes partly from increasing demands such as population, industry and domestic requirements and partly from consequences of climatic change(Awulachew, 2006). Therefore, great emphasis is placed in the area of crop physiology and crop management with the aim to make plants more efficient in water use under dry condition(Stikic *et al.*, 2003).Partial root zone drying is a practice of using irrigation to alternately wet and dry (at least)two Spatially prescribed parts of the plant root system to simultaneously maintain plant water status at maximum water potential and control vegetative growth for prescribed parts of seasonal parts of plant development (Sepaskhah and Ahmadi, 2012).

The concept of alternate furrow irrigation is that:

- In alternate furrow irrigation less surface water is wetted and less evaporation from the surface occurs.
- More lateral roots are stimulated and a chemical signal is produced in drying roots to reduce the shoot water loss.
- The amount of water needed (irrigation water use), time and labor requirement for Irrigation is decreased.
- Water use efficiency was nearly doubled by using this method.

Material and methods

Description of the study areas

The study was conducted for one irrigation seasons 2017/18 in woleh on five farmer trial site about15km from Sekota town. Sekota woreda is one of the woreda in wag-himra zone administrative of Amhara region. The experimental sites are found within 1384757N and 505143 E of longitude and an altitude of 2119m. The Agro-climatically of the woreda is situated in dry areas. The meteorological data was used extrapolated from nearby station abiady; maychew and Lalibela were used for the designing of irrigation infrastructures. The long term average ETO in the study area was 4.47mm/day. The mean annual maximum temperature ranges from 23.1^{oc} to28.6^{oc}. The woreda receives annual average rainfall of the area ranges from 329mm to 833mm. most of the rain is received from the fourth week of June to the end of August. The coincidence of late onset, early cessation and uneven distribution of rainfall with short effective season has resulted terminal dry spells, recurrent drought and unreliable rain-fed cropping in the area.

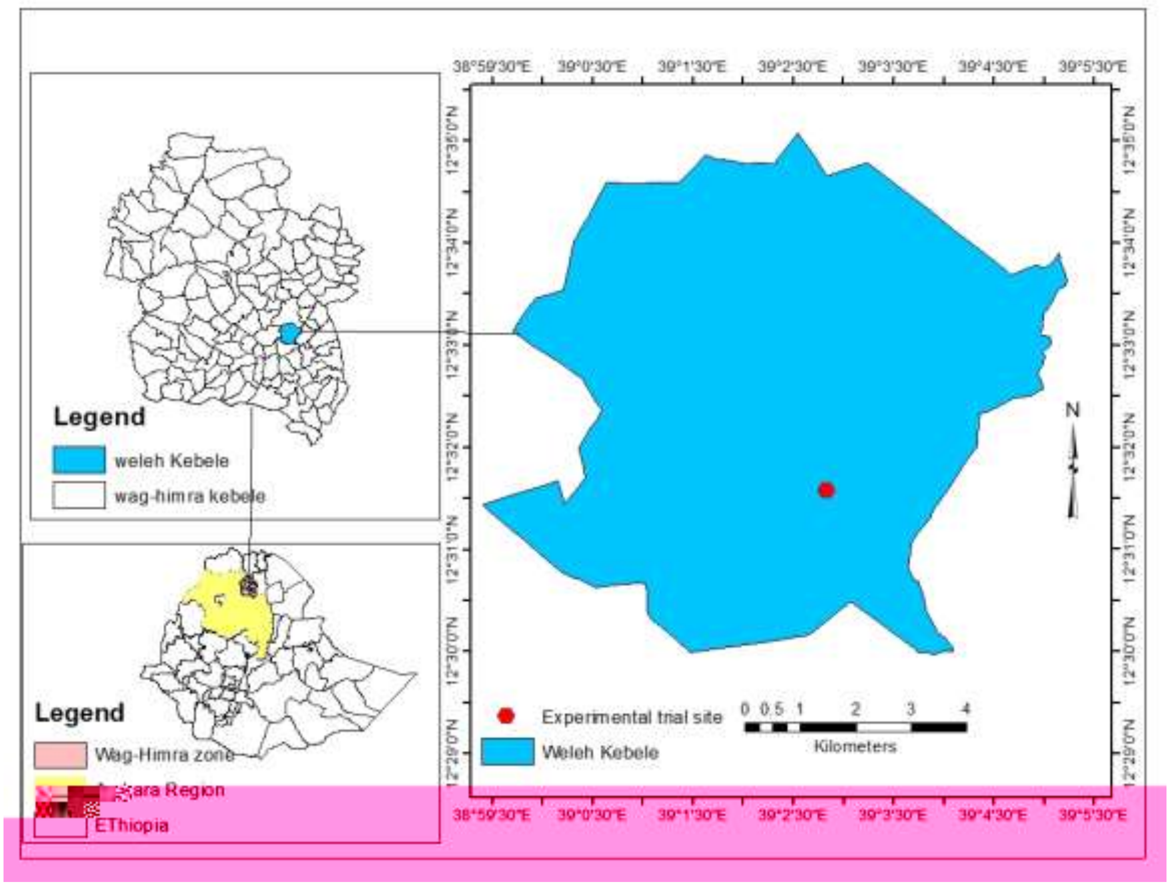

Figure1. Map of the study area

Crop selection and crop agronomy in the study areas

The most important irrigable crops in the irrigation schemes were identified in terms of crop type, market opportunity, crop variety and length of growing season. Considering all these factors, onion with Bombay red variety was selected as experimental crop. The experiment of onion variety has a total growing period of 115 days including transplanting up to harvesting with the initial crop growth stage about 20 days, crop development stage of 30 days, midseason Stage of 40 days and late season stage of 25 days, which was derived from CROPWAT software. The experimental plot size of 10m×10m double row planting with spacing of 40cm×20cm×10cm (between rows including the furrow × between rows on the bed × between plants in a row) were used respectively. The spacing between the plots was 1m. Blanket recommended fertilizer rate of NPS 100kg at transplanting and urea fertilizer of 200kg at half transplanting and half 45 days was applied in experimental sites. Both diseases and weed infestation was regularly monitored, and proper management action has been undertaken timely. Thribes were observed during the early seedling establishments on the actual field, vegetative and plant development stages. Profit was used to control the disease infestation which was practiced by protection researcher recommendation

Crop Water Requirement of onion

Calculation of crop water requirement, net irrigation requirement, and schedule of the water application were carried out with inputs of soil, climatic and crop data's, and the CROPWAT Computer model was implemented for undertaking the operation. The model requires crop data such as crop type, planting date, growth stage days, maximum rooting depth, Kc values, depletion fraction and yield reduction coefficient and climatic data including maximum and minimum Temperature, rainfall, wind, sun shine hours and relative humidity and soil type. Climatic data of the experimental sites were collected from neighboring stations and extrapolated using LocClim Software. For calculating the crop water requirement, given the input of the required data, the reference evapotranspiration was calculated first using the Penman-Monteith equation in the CROPWAT program (Allen *et al.,* 1998). Composite soil samples were collected from field plots and the soil textural analysis was done soil analysis method and soil textural class was determined from soil textural triangle. Field capacity, permanent wilting point, and moisture at saturation were determined from laboratory analysis of soil samples.

Total Available Moisture (TAM) in the soil for the crop during the growing season was calculated as Field capacity (FC) minus wilting point (PWP) times the current rooting depth (D)of the crop as indicated in the following relation. TAM= (FC-PWP)*D. Readily Available Moisture (RAM) was calculated as TAM*P, Where P is the depletion fractions defined by the crop coefficient (Kc) files. The estimated crop water requirements were converted in to the field irrigation water requirement. The net irrigation requirement (NIR (mm/period)) was determined based on the equation. NIR=CWR - Peff, where, CWR=crop water Requirement (mm/period), Peff=Effective precipitation. The exact volume of water needed to fulfill the irrigation water requirement throughout the growing season was calculated using thee equation below.

$$\text{Gross irrigation requirement (mm)} = \frac{\text{Net irrigation requirement (mm)}}{\text{Application efficiency}}$$

Water productivity, also known as water use efficiency, was determined as the ratio of crop yield per unit area, in terms of grain, to crop evapotranspiration (mm), and was expressed as kg of grain or biomass per m^3 of consumed water.

$$\text{Water use efficiency } (kg/m^3) = \frac{\text{total yield of onion (bulb)}}{\text{Water delivered up to harvesting}}$$

Furrow irrigation was the method used for applying water for this experiment. Since water is applied directly to the plot; conveyance and distribution losses was ignored and 90% irrigation application efficiency was taken.

Experimental set up

The design of the experiment was RCBD with four as farmer replications. In field experiment three furrow irrigation water application methods were verified. Alternate furrow irrigation (AFI), Conventional furrow irrigation (CFI) and fixed furrow irrigation (FFI) and the recommended irrigation amounts; of 75%. The Alternate furrow irrigation means that one of the two neighboring furrows was alternately irrigated during consecutive watering. Fixed furrow irrigation means that irrigation was fixed to one of the two adjacent furrows while the Conventional furrow irrigation was the conventional way where every furrow irrigated during each watering. The frequency of irrigation water was applied at 5 days irrigation interval, hence all plots was irrigated 20 times throughout the growing season. There was 1.2mm of rainfall throughout the growing season. Prior to planting all plots were irrigated with equal amount of water up to the field capacity. Weeding and other agronomic practices were conducted on time equally for each treatment. Hand held watering Cane was used to control the amount of water entering each furrow. Agronomic parameters like bulb diameter, plant height, marketable yield, unmarketable yield, total yield and water productivity were collected as per the schedule.

Data analysis

All the agronomic, yield and water productivity data were recorded and being subjected to analysis. Analysis of variance was performed using Statistix 10.0 statistical Software. Effects were considered significant in all statistical calculations if the P-values were ≤ 0.05. Means were separated using Fisher's Least Significant Difference (LSD) test.

Treatment set up

1. 75 % CROPWAT fixed depth and Alternate furrow irrigation (AFI) at 5 days interval.
2. 75 % CROPWAT fixed depth and Conventional furrow irrigation (CFI) at 5 days interval.
3. 75 % CROPWAT fixed depth and Fixed furrow irrigation (FFI) at 5 days interval.

Results and discussion

The results of the experiment shows that, there was no statistically significance difference in the plant height, marketable and unmarketable yield of onion on the application of 75% amount of irrigation water at five days irrigation intervals on alternate and conventional furrow irrigation methods(Table1).But there was significant difference in bulb diameter and water productivity (Table 1&2).AFI enables more efficient use of irrigation water associated with some water stress compared to CFI this is why significant difference in bulb diameter as well as water productivity. However, the analysis result on irrigation type showed that application of alternative furrow irrigation type has a statistical significance difference in all parameter as compared to fixed furrow except bulb diameter. It is obvious that conventional furrow irrigation is labour intensive and time consuming, each furrow is irrigated at each frequency of irrigation, and however, alternate irrigation consumes half of the labour, time and amount of required irrigating. In addition to this advantage in the experimental result alternate furrow irrigation with 75% of irrigation water saves the highest total yield of 122.9qt/ha while the conventional and fixed ones with double amount of water application gave 132qt/ha and 96qt/ha total yield respectively. This result in line with the finding of (Birru *et al.,* 2010) alternate furrow irrigation was achieved better total and marketable yield of potato as compared to conventional and fixed ways of furrow irrigation methods. On the other hand the finding of (Gelu, 2018) stated that alternative furrow irrigation system in areas where there is water scarcity as well as labor expensiveness is the best options to increase the production of onion and other vegetables.

Figure 2. Field status of the experimental plot

Table 1. Mean bulb diameter, plant height, marketable, total and unmarketable yield of onion in 2017/2018

Treatment	Ph(cm)	Bd(cm)	My(qt/ha)	Unmy(qt/ha)	Ty(qt/ha)
AFI	50.4[a]	4.31[b]	120.03[a]	2.89	122.92[a]
CFI	50.3[a]	4.68[a]	129.47[a]	3.13	132.6[a]
FFI	47.01[b]	4.32[b]	92.82[b]	3.34	96.16[b]
CV (%)	1.11	1.9	5.08	15.82	5.15
LSD(0.05)	0.95	0.14	10.03	NS	10.45

Means with the same letter are not significant different. Bd= bulb diameter; ph= plant height; my= marketable yield; Ty=total yield; Unmy= unmarketable yield

As shown in Table1 the marketable onion bulb yield was obtained from CFI (129.47qt/ha) and AFI (120.03qt/ha) systems were significantly different from FFI (92.82qt/ha) system. The statistical analysis onion crop yield obtained in our experiment is presented in Table 1. It shows that the difference in onion crop yield obtained with CFI and AFI was non-significant. However, A slightly yield reduction obtained by AFI compare with CFI.A slight reduction in crop yield with AFI compared to CFI was also reported by (Sepaskhah and Ghasemi, 2008, Rafiee and Shakarami, 2010).The results also in agreement with the finding of (Slatni *et al.*, 2011, Crabtree *et al.*, 1985)using alternative furrow irrigation methods insignificant a yield reduction on sorghum and soybeans production as compared to conventional furrow irrigation methods. This is also supported by (Stone and Nofziger, 1993)who found that AFI may result insignificant cotton yield production because too little water is applied, particularly when evaporative rates are very high. Under the AFI method, the onion plant root system was partially wetted which could result in reduced stomata conductance and a reduction in plant transpiration. Photosynthesis and dry matter accumulation can however be less affected by this partial stomata closure (Kang *et al.,* 2000) and also the roots on the irrigated side of the furrow (wet soil) will continue to take up water to try and meet the required water demand of the plant(Ahmadi *et al.,* 2010). Zhang *et al.* (1987)reported that plants with two halves of their root system under alternate drying and wetting cycles resulted in reduced stomatal opening but without significant increase in leaf water deficit. This could be part of the reason why there was a non-significant reduction in crop yield with AFI compared with CFI. Kang *et al.* (2000) also observed a high grain yield for maize when subjected to a half reduction in the amount of irrigation applied. Sepaskhah and Ahmadi (2012)also recommended partial root zone drying (similar to AFI) for better fruit quality and increased crop water productivity in areas with limited water resources. Table 2 shows the crop water productivity of AFI, CFI and fixed methods for growing onion. The highest water productivity of 4.05kgm^{-3} was obtained with AFI followed by FFI with 3.16kgm^{-3} and conventional furrow irrigation, which had the lowest water productivity of 2.15kgm^{-3}.It shows that the variation in WP for all treatments were highly significant, which highlights the effect the method of irrigation has on water productivity. Ibrahim and Emara (2010)reported that the AFI method had higher WP compared with the CFI method. Slatni *et al.* (2011)reported that AFI resulted in a slight decrease in crop yield but increased water productivity.(Rafiee and Shakarami, 2010) also reported that AFI enables more efficient use of irrigation water but with a lower crop yield associated with some water stress compared to CFI. There was a significant reduction of 75%in the volume of water applied to the AFI treatments. This means 6076m^3 volume of water is needed to irrigate 1 hectare area in CFI system which is enough to irrigate 2 hectare area of land in AFI system. So, when the area to be irrigated becomes double in AFI system using the saved volume of water, the yield obtained also becomes double. The reason why the yield result is well performing as compared to CFI system is probably because of a better application efficiency and physiological response associated with AFI (Kang *et al.,* 2000, Zhengbin *et al.*, 2011)and less evapotranspiration associated with AFI (Gelu G, 2018).This result conformity with (Abdel-Maksoud *et al.*, 2002, Tavakkoli and Oweis, 2004)applied the same amount of water alternate furrow irrigation obtained highest maize and wheat grain yield production and water productivity as contrast to conventional and fixed furrow irrigation techniques. In addition to that (Nouri and Nasab, 2011)accomplished that the alternate furrow irrigation system generally increases sugar cane production, water productivity and field water use efficiency.

Table 2. Effect of applied water and furrow irrigation method on water productivity of onion

Treatment	Number of irrigation	Irrigation water(m^3/ha)	Total yield (t/ha)	Water productivity (kg/m^3)
75%AFI	20	3038	12.29[a]	4.05[a]
75%CFI	20	6076	13.26[a]	2.15[c]
75%FFI	20	3038	9.62[b]	3.16[b]
CV (%)	_	_	5.15	10.07
LSD (0.05)	_	_	10.45	0.45

In field experiment observed that conventional furrow irrigation is labor intensive and time consuming each furrow is irrigated at each frequency of irrigation and however, alternate irrigation consumes half of the labor, time and amount of required irrigating. In addition to this advantage in the experimental result alternate furrow irrigation saves the highest total yield of 12.29ton/ha while the conventional (double amount of water) and fixed furrow irrigation system gave13.2ton/ha and 9.39ton/ha total yield respectively.

Therefore, in areas with scarce water resource for irrigation in Sekota woreda or agro climatically similar areas can use 75% (3038m^3/ha) of water at five days interval in alternate furrow irrigation methods irrigation water application throughout the whole growing season was obtained optimum total yield production of irrigated onion.

Table 3. Economic water productivity of onion in alternate furrow irrigation (AFI), conventional furrow irrigation (CFI) and fixed furrow irrigation (FFI**).**

Treatment	Total Gross benefits (TGB) birr/ha	Irrigation water(m^3/ha)	Economic water productivity (WP(e)) birr/m^3
AFI	110610	3038	36.41
FFI	84510	3038	27.81
CFI	119610	6076	19.68

Table 3 shows that economic water productivity (WP (e)) of onion crops in the AFI, FFI and CFI irrigation methods the highest (WP(e)) 36.41birr/m3was obtained in AFI followed by FFI with 27.81birr/m3 and CFI irrigation 19.68birr/m3 which had the lowest Economic water productivity(WP(e)).

Table 4. Partial budget analysis for the experimental irrigation treatments

Treatment	Unadjusted yield(t/ha)	Adjusted bulb yield by 10% (t/ha)	Total gross benefits (birr/ha)	Total cost that vary (birr/ha)	Net benefits (birr/ha)	MRR
AFI	12.29	11.061	110610	12490.63	98119.37	785.543
FFI	9.39	8.451	84510	12490.63	72019.37	D
CFI	13.29	11.961	119610	24981.27	94628.73	-27.946

Table 4 indicated that for every birr 1.00 invested in Conventional furrow Irrigation the farmers including 1.00birr 27.71birr was loosed and obtained an additional 7.85birr after recovering on Alternative furrow Irrigation. Since MRR>100% adopting AFI is economically feasible. The total cost mainly included operating and variable Operating costs (land preparation, seeds, Fertilizer and chemicals) were based on the planted area. Therefore, the operating costs of the AFI treatments were the same as the conventional CFI and FFI treatment. Variable costs depended on the number of irrigation events and water unit price. The water unit price was estimated to be 3.5birr/1000m3 according to irrigation water prices of Awash River basin Authority(Ayana et al., 2015). Total water cost for each season was calculated by multiplying the water unit price by the total amount of irrigation water required for the onion crop.

Therefore10.633birr/3038m3for AFI and FFI where as 21.266birr/6076m3 for CFI and the labor cost due to irrigation events are 12480birr to AFI and FFI but 24960birr for CFI which shown that higher cost in labor as well as water price than the two.

Conclusion and Recommendations

Results obtained from this study show that, in AFI system the total water used was half of CFI system, but the onion yield obtained was slightly reduced due to high evaporation with little amount of water applied despite of AFI provides CFI this Significant amount of water (3038m3/ha) was saved by AFI system while it also maintains onion yield. So, AFI is water saving irrigation method was suited for onion production without a significant bulb yield loss with maximum water productivity.

AFI systems saved labor and time used for irrigation water which is half of CFI system. Because in CFI system four furrows irrigated at same time while in AFI only two furrows out of four furrows. This may improves working conditions as technology allows irrigator moving on the dry furrows.

This reduction in applied water is also important to minimize the risks of soil sod city development in irrigated area, especially when the quality of irrigation water deteriorated. Rather than using 6076m3/ha of water for 1 hectare in CFI system, it is possible to double the irrigated area to 2 hectares in AFI system. Onion needs high amount of irrigation water during the development stage, but in FFI system as half of the root stay dry throughout the growth period, continuous stress significantly reduces fresh bulb yield.

Alternative furrow irrigation system is the best technology among the tested technologies to be recommended for the communities of the study area, because of its high water application efficiency, yield performance, in addition to time, labour and irrigation cost saving. So alternative furrow irrigation system in areas where there is water scarcity as well as labor expensiveness is the best options to increase the production of onion.

Therefore, it is advised that areas with insufficient water resource for irrigation in Sekota or agro

climatically similar areas can use of 75% (3038m3) of irrigation water at five days interval in alternative furrow irrigation methods throughout the growing season, for optimum production of irrigated onion.

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