Effect of Alternate Furrow Irrigation and Amount of Water on Water Productivity and Yield of Potato in East Belesa

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ABSTRACT
Three irrigation methods: conventional furrow irrigation (CFI), fixed furrow irrigation (FFI) and alternating furrow irrigation (AFI) were tested on three separate plots. Each irrigation method was further divided into three treatments using different irrigation amount: i.e. 22 mm, 16 mm and 11 mm water for each watering at 7 days interval, were tested for irrigated potato in East Belesa over 2 years (2006–2007). It was found that alternate furrow irrigation gives a significantly higher yield advantage than the conventional and fixed way of furrow irrigation. Alternate furrow irrigation with 22 mm of irrigation water gives the highest total yield (19509 kg/ha) while the conventional and fixed one with the same amount of water gives 13566 and 13663 kg/ha total yield respectively. There is also significant difference among the treatments in water productivity. The comparison of irrigation methods shows that there is significant difference in marketable and total yield between alternate and conventional as well as between alternate and fixed furrow irrigation methods, whereas no significant difference obtained between fixed and conventional furrow irrigation methods. Alternate furrow irrigation method gave significantly high yield and water productivity than the conventional and fixed furrow irrigation methods. Similarly, there is no significant difference among the three irrigation water amounts both in marketable and total yield of potato in East Belesa. However, the combined mean result shows 22 mm of applied water gave the highest marketable and total yield of potato.

Based up on the two years combined result alternate furrow irrigation with 22 mm of applied water at 7 days interval gives the highest yield of potato compared with other treatment combination in East Belesa. Hence, it is advised that farmers in East Belesa should use alternate furrow irrigation for better and efficient production of potato. However, further research required to accurately determine the amount of irrigation water for alternate furrow irrigation method for maximum production of potato in East Belesa.

Key words: *Alternate furrow irrigation, East Belesa, Irrigation amount, Water productivity, Yield of potato*

INTRODUCTION

Amhara region, with a population of about 18 million, faces both chronic and transitory food insecurity due to a combination of factors including erratic and unreliable rainfall, degraded resource base, high population to cultivated land ratios and low productivity related to management practices (BoARD, 2003). As a result of these and other factors, an estimated 18-20% of the population is chronically food insecure. Recognizing this fact, the regional government has prioritized the provision of reliable irrigation water (supplementary and/or full) to reduce the incidence of drought related crop failures as prerequisite for increasing agricultural productivity to reduce the level of household food insecurity (BoWRD, 2005).

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. Agronomic measures such as varying tillage practices, mulching and anti-transpirants can reduce the demand for irrigation water and improve irrigation water use efficiency (IWUE). Development of novel water saving irrigation techniques represents another option for increased water use efficiency. During the last two decades, water–saving irrigation techniques such as deficit irrigation (DI) and partial root zone drying (PRD) or alternative irrigation (AI) 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-Domínguez, 2003).

Alternate irrigation is a new irrigation technique which requires that approximately half of the root system is always exposed to drying soil while the remaining half is irrigated as in full irrigation. The wetted and dried sides of the root system are alternated in a frequency according to crops, growing stages and soil water balance. This technique has the potential to reduce crop water use significantly, increase canopy vigor, and maintain yields when compared with normal irrigation methods. This technique has two theoretical assumptions. (i) Fully irrigated plants usually have widely opened stomata. A small narrowing of the stomata opening may reduce water loss substantially with little effect on photosynthesis (Jones, 1992). (ii) Part of the root system in drying soil can respond to drying by sending a root-sourced signal to the shoots where stomata may be closed to reduce water loss (Davies and Zhang, 1991).

Ideally, WUE 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. The advantage of such regulation is that plant may delay the onset of an injurious leaf water deficit and enhance its chance of survival under unpredictable rainfall conditions. More recent evidence has shown that such a feed forward stomatal regulation process works through a chemical signal. The increased concentration of abscicie acid (ABA), in the xylem flow soil can produce large amount of ABA while the rest of the root system in wet soil may function normally to keep the plant hydrated (zhang and devise 1987). The result of such a response is that the plant may have a reduced stomatal opening in the absence of a visible leaf water deficit.

Fischbach and mulliner (1972) reported that alternate furrow irrigation in cash crops offer the opportunity for reduced water use and increased WUE. Alternate furrow irrigation was practiced for a number of crops such as potato, tomato, soybean and corn to conserve water. In a study on tomato on Orissa (India), alternate furrow irrigation gave the highest WUE (5,140 Kg ha^{-1} mm^{-1}) among several furrow treatments (Sahoo et. 1998)

The hypothesis behind irrigating alternate furrows is that:

1. In alternate furrow irrigation less surface water is wetted and less evaporation from the surface occurs.
2. More lateral roots are stimulated and a chemical signal is produced in drying roots to reduce the shoot water loss.
3. Amount of water needed (i.e. irrigation water use), time and labor requirement for irrigation is decreased.
4. Water use efficiency (WUE) will be nearly doubled by using this method.

In Ethiopia there were no research works on alternate furrow irrigation and water resources are used inefficiently even in water deficient areas. But there are not any researches in our country regarding alternate furrow irrigation for better yield of potato while utilizing water resources efficiently. Thus, this study was initiated to evaluate efficiency of alternate furrow irrigation and amount of water on water productivity and yield of potato.

MATERIALS AND METHODS

Description of Study Area

The study was conducted for two consecutive years from 2006 to 2007 in Dengora about 7km from Gohala, woreda capital of East Belesa. East Belesa is one of the woredas in North Gondar Administrative Zone of Amhara Region. It is bordered with Janamora and Wogera in the North, Ebinat in the South, West Belesa in the West and Wagehamera zone in the East. Geographically the woredas lies between 35^0 52’ to 38^0 39’E and 11^0 38’ to 13^0 32’ N. The woreda has a total area of 1,563 Km^2. The woreda capital Gohala is located 160 Km from Bahir Dar town.

Agro climatically the woreda is located in dry sub humid area. In the Woreda there is no meteorological station. Data from nearby station, Addis Zemen, was used for the designing of irrigation infrastructures. The maximum ET_0 in the area is 5.8 mm/day in March. The mean annual temperature ranges from 22^0C to 25^0C. The woreda receives annual average rainfall of 600-800mm. 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 rainfed cropping in the area.

The woreda is endowed with 15 perennial rivers and a number of small springs and streams. The rivers and springs are used for water supply and irrigation. Besides, there exist developed water points and household water harvesting structures. Currently there are 8 traditional and 3 modern irrigation schemes, which can have a capacity to irrigate around 310ha of land, operating in the woreda. In most of the irrigation schemes, whether traditional or modern, the irrigation water management practices followed by farmers are traditional and poor water management. The soil in the experimental site is Cambsols, texturally clay loam. The effective soil depth in the experimental site is moderately deep (150 cm) with moderate fertility.

Methodology

In the field three different methods of furrow irrigation were tested for irrigated potato in East Belesa over 2 years (2006–2007). Irrigation water was applied through furrows in three ways: alternate furrow irrigation (AFI), fixed furrow irrigation (FFI) and conventional furrow irrigation (CFI). AFI means that one of the two neighboring furrows was alternately irrigated during consecutive watering. FFI means that irrigation was fixed to one of the two neighboring furrows. CFI was the conventional way where every furrow was irrigated during each watering. Each irrigation method was further divided into three treatments with different irrigation amounts, i.e. 11, 16, and 22 mm water for each watering.

The test plant was potato (*Solanum Tuberosum*) of variety *'Gera*'. The plot size was 3m x 6m. The spacing between plants was 30cm and between rows 75 cm. The spacing between treatments was 1m and the spacing between each block was 2m. Potato was planted on January 13 and harvested on May 02 with the length of growing period around 125 days. The frequency of irrigation was fixed as 7 days interval, hence all plots was irrigated 18 times throughout the growing season. The design of the experiment was RCBD with three replications. Prior to planting all plots was irrigated with equal amount of water up to the field capacity to initiate germination. There is no rainfall throughout the growing season. Finally, prior to harvest, 10 plants were sampled at random from central three rows of each plot for determination of agronomic parameters. Data collected include total, marketable, and unmarketable (decay, split, and under weight) yield, tuber diameter, number of tubers, and tuber weight.

RESULTS AND DISCUSSION

Analysis of variance was conducted by combining two years of irrigation season data using SAS statistical software. The combined result shows that there is significant difference for total and marketable yield of potato among treatments (see Table 1). However, in the first year, there is no statistically significance difference in the total and marketable yield of potato. The mean total and marketable yield of potato of alternate furrow irrigation with 22 mm of applied water is significantly different from the conventional and fixed way of furrow irrigation. It is obvious that conventional furrow irrigation is labour intensive and time consuming, each furrow is irrigated at each frequency of irrigation, however, alternate irrigation consumes half of the labour and time required to irrigate. In addition to this advantage in this experimental result alternate furrow irrigation with 22 mm of irrigation water saves the highest total yield (19509 kg/ha) while the conventional and fixed ones with the same amount of water gives 13566 and 13663 kg/ha total yield respectively.

Stem diameter, number of tubesr, and tuber weights did not significant difference among treatment, as it is shown on Table 2. Average number of tubers and diameter of tuber is also highest in alternate furrow irrigation than the other two. It is only with fixed furrow irrigation with 11 mm of irrigation water that the highest tuber weight (80.24 gm) was recorded.

Table 1 Mean Marketable and Total Yield of Potato for the Whole Experimental Season in East Belesa

	Year 1/2006		Year 2/2007		Combined	
Treatment	Total Yield (kg/ha)	Marketable Yield (kg/ha)	Total Yield (kg/ha)	Marketable Yield (kg/ha)	Total Yield (kg/ha)	Marketable Yield (kg/ha)
22mm & CF	13309	12983	14830BA	14148BA	14069B	13566B
16mm & CF	14035	13487	13156B	12133B	13595B	12810B
11mm & CF	15418	14736	15855BA	15262BA	15636BA	14999BA
22mm & FF	15752	15026	12759B	12300B	14256B	13663B
16mm & FF	13823	13096	14863BA	14063BA	14343B	13579B
11mm & FF	13816	12942	15870BA	14685BA	14843B	13814B
22mm & AF	**18485**	**17907**	**20533A**	**19822A**	**19509A**	**18864A**
16mm & AF	16173	15729	17393BA	16756BA	16783BA	16383BA
11mm & AF	15196	14574	17437BA	17037BA	16317BA	15665BA
C.V (%)	20.12	21.39	26.91	26.96	22.29	22.73
Fisher's LSD (0.05)	ns	ns	7319	6999	4018	3916

- ns = non significant difference at 5% significant level
- Means with the same letter are not significant different

Table 3 shows values of water productivity, quantifies changes in crop yield per m^3 irrigation water supplied. There is significant difference among the treatments in water productivity. Alternate furrow irrigation with 11 mm of applied water gives the highest water productivity; in fact the conventional furrow irrigation with 11 mm of irrigation water also shows almost equal water productivity as that of the alternate furrow irrigation. Therefore, in areas with insufficient water resource for irrigation in East Belesa or agro climatically similar areas can use 11 mm (110 m^3/ha) of water at 7 days interval, or 1980 m^3/ha of water through out the growing season, for optimum total yield production of irrigated potato. However, to get maximum total yield of potato in East Belesa farmers are advised to use at least 22 mm (220 m^3/ha) of water at 7 days interval, or 3960 m^3/ha of water through out the growing season.

Table 2 Average Number of Tubers, Tuber Weight and Diameter of Tuber of Potato for the Whole Experimental Season in East Belesa

	Year 1/2006			Year 2/2007			Combined		
Treatment	Av. No. tubers	Av. Tuber Weight (gm)	Av. Diameter of tuber (cm)	Av. No. tubers	Av. Tuber Weight (gm)	Av. Diameter of tuber (cm)	Av. No. tubers	Av.Tuber Weight (gm)	Av. Diameter of tuber (cm)
22mm & CF	3.87	67.13	34.40	5.07	66.57	33.53	4.47	66.9	33.97
16mm & CF	4.53	73.47	32.40	6.87	44.24	33.07	5.7	58.85	32.73
11mm & CF	4.47	82.10	33.80	6.20	58.60	34.00	5.33	70.35	33.90
22mm & FF	3.87	102.20	33.33	6.13	47.53	33.67	5.00	74.87	33.50
16mm & FF	3.33	72.73	31.07	6.27	56.06	31.60	4.80	64.40	31.33
11mm & FF	3.87	**109.47**	32.40	7.53	51.01	31.13	5.70	**80.24**	31.77
22mm & AF	4.33	70.40	32.80	**8.40**	56.78	32.80	6.37	63.59	32.80
16mm & AF	5.00	87.73	32.00	5.60	**71.58**	31.40	5.30	79.66	31.70
11mm & AF	**5.07**	62.60	**35.33**	7.40	56.60	**34.07**	**6.23**	59.60	**34.70**
C.V (%)	28.33	39.49	9.62	33.35	24.84	5.43	39.00	40.45	7.11
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns

- ns = non significant difference at 5% significant level

By separating the combined effect of irrigation method and amount of irrigation the data was analyzed separately for irrigation method as it is shown in Table 4. In 2006 irrigation season even if statistically there is no significant difference among irrigation methods both for marketable and total yield of potato, the mean marketable and total yield obtained with alternate furrow irrigation is higher than the fixed and conventional furrow irrigation methods. There is significant difference in marketable and total yield between alternate and conventional as well as between alternate and fixed furrow irrigation methods in 2007 experimental year and the two years (2006 and 2007) combined result. However, there is no significant difference between fixed and conventional furrow irrigation methods. Alternate furrow irrigation method gives significantly high yield and water productivity than the conventional and fixed furrow irrigation methods.

Table 3 Effect of Applied Water and Furrow Irrigation Method on Water Productivity of Potato in East Belesa

Treatment	Number of irrigation	Irrigated water (m^3/ha)	Total Yield (kg/ha)	Water Productivity (kg/m^3)
22mm & CFI	18	3960	14069B	3.55C
16mm & CFI	18	2880	13595B	4.72CB
11mm & CFI	18	1980	15636BA	7.90A
22mm & FFI	18	3960	14256B	3.60C
16mm & FFI	18	2880	14343B	4.98CB
11mm & FFI	18	1980	14843B	7.50A
22mm & AFI	18	3960	**19509A**	4.93CB
16mm & AFI	18	2880	16783BA	5.83B
11mm & AFI	18	1980	16317BA	**8.24A**
C.V (%)	-	-	22.29	**23.21**
Fisher's LSD (0.05)	-	-	4018	**1.53**

Table 4 Effect of Irrigation Methods on Marketable and Total Yield of Potato in East Belesa

Irrigation Method	Year 1/2006		Year 2/2007		Combined		
	Marketable Yield (kg/ha)	Total Yield (kg/ha)	Marketable Yield (kg/ha)	Total Yield (kg/ha)	Marke-table Yield (kg/ha)	Total Yield (kg/ha)	Water Productivity (kg/m^3)
Alternate Furrow Irrigation (AFI)	160.70	166.18	17872A	18454A	16971A	17536 A	6.33
Conventional Furrow Irrigation (CFI)	137.35	142.54	13848B	14613B	13792B	14434 B	5.39
Fixed Furrow Irrigation (FFI)	136.88	144.64	13683B	14498B	13685B	14481 B	5.36
Coefficient of Variation (CV %)	20.08	19.00	24.91	24.87	22.35	21.91	36.59
Fisher's LSD (0.05)	ns	ns	3668	3837	2216	2270	ns

- Means with the same letter are not significant different
- ns = non significant difference at 5% significant level

Fixed furrow irrigation gives low total and marketable yield as compared to alternate furrow irrigation. This is because it is only one side of potato root system that is wetted for the whole irrigation season, the roots in the dried soil encountered shortage of moisture; hence, nutrient uptake from the soil is reduced, which affect the physiology of the crop and as a result the plant did not maintain the yield. However, in the alternate furrow irrigation each of the furrow gets water at 14 days interval. Even if there was a moisture stress on one side of the plant after 7 days from the previous irrigation, this stress was overcome by stomata closure to reduce water loss and a chemical signal is produced in drying roots to reduce the shoot water loss.

Conventional furrow irrigation saves similarly low yield as that of fixed furrow irrigation as compared to alternate furrow irrigation. The reason is that in conventional furrow compared to alternate furrow irrigation. Average number of tubers and diameter of tuber was also highest in alternate furrow irrigation than the other two.

Among the treatments alternate furrow irrigation with 11 mm of applied water saves significantly highest water productivity. Therefore, in areas with scarce water resource for irrigation in East Belesa or agro climatically similar areas can use 11 mm (110 m^3/ha) of water at 7 days interval, or 1980 m^3/ha of water through out the growing season, for optimum production of irrigated Potato. However, to get maximum total yield of potato in East Belesa farmers are advised to use at least 22 mm (220 m^3/ha) of water at 7 days interval, or 3960 m^3/ha of water through out the growing season.

By separating the combined effect of irrigation method and amount of irrigation the data was analyzed separately for irrigation method. The result shows that there is significant difference in marketable and total yield among irrigation methods in the two year experimental season. Therefore, the two years combined result shows that alternate furrow irrigation method gives significantly higher yield than the other two irrigation methods at 5% significance level. Similarly, in the two consecutive years of irrigation, statistically there is no significant difference among the three irrigation amounts both in marketable and total yield of potato in East Belesa. However, the combined mean result shows 22 mm of applied water gives the highest marketable and total yield of potato in East Belesa.

Based up on the two years combined result, alternate furrow irrigation with 22 mm of applied water at 7 days interval gives significantly highest total and marketable yield of potato compared with other treatment combination in East Belesa. Hence, it is advised that farmers in East Belesa area use alternate furrow irrigation for better and efficient production of potato. However, the irrigation amount treatments are few in number to show precisely water yield production function, hence, further research is required to accurately determine the amount of irrigation water for alternate furrow irrigation method for maximum production of potato in East Belesa.

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