academicresearchJournals

Vol. 6(8), pp. 488-494, October 2018
DOI: 10.14662/ARJASR2018.079

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Full Length Research

# Integrated Effect of Different Mulching and Furrow Irrigation Techniques on Potato (*Solanum tuberosum L*) Yield and Water Productivity at Kulumsa, Ethiopia

**Samuel Lindi[1], Mehiret Hone[1], Eliyas Meskelu[2], Bakasho Iticha[1], Wubengida Admasu[1], and Kassu Tadesse[1]**

[1]Kulumsa Agricultural Research Center, P.O.Box 489, Asella, Ethiopia. (corresponding Author)
Email: samuellindi5@gmail.com,
[1]Kulumsa Agricultural Research Center, P.O.Box 489, Asella, Ethiopia.
[2]Wendogenet Agricultural Research Center, P.O.Box 2003, Wendo, Ethiopia,

Accepted 4 October 2018

**The experiment was conducted at Kulumsa Agricultural Research Center, Tiyo District, which is located in Arsi Zone, Ethiopia during the dry season of 2014/15, 2015/16, 2016/17 and 2017/18 based on the objective to select most effective water saving techniques and improve water productivity of irrigated potato. Three types of furrow irrigation methods (alternate, fixed and conventional furrow), two mulch types (straw and plastic) and no mulch (as control) with three replications in split plot design was arranged. The over years analysis of variance revealed that, different types of irrigation and mulch types highly significantly (p<0.01) affected potato tuber yield and water productivity. Potato tuber and biological yield was highly significantly (p<0.01) influenced due to different mulch types used. In addition to this, the interaction effect of irrigation methods and mulch types had a significant (p<0.05) effect on tuber yield of potato. The maximum and minimum tuber yield of 44,866 and 39,782 kg/ha were obtained at conventional and fixed furrow irrigation methods, respectively. The maximum and minimum tuber yield of 44,136 and 39,218 kg/ha were obtained under straw and plastic mulch application, respectively. The interaction effect showed that higher tuber yield of 50,452 kg/ha was obtained at conventional furrow under straw mulching. Under deficit treatments, the higher tuber yield of 41,942kg/ha was obtained at alternate furrow irrigation under straw mulch. Therefore, for maximizing tuber yield production of potato under no water stress scenario, irrigation should be done with conventional furrow irrigation with straw mulching. On the other hand, under limiting water resource, irrigation of potato could be done with alternate furrow irrigation method with straw mulch for maximizing water productivity of potato at Tiyo district and similar agro-ecology and soil type.**

**Key words:** alternate furrow, conventional furrow, fixed furrow, plastic mulch, straw mulch, potato, water productivity

**Cite this article as**: Lindi, S., Hone, M., Meskelu, E., Iticha, B., Admasu, W., Tadesse, K. (2018). Integrated Effect of Different Mulching and Furrow Irrigation Techniques on Potato (*Solanum tuberosum L*) Yield and Water Productivity at Kulumsa, Ethiopia. Acad. Res. J. Agri. Sci. Res. 6(8): 488-494

## INTRODUCTION

Irrigation is an age-old art-perhaps as old as human civilization. Nevertheless, the increasing need for crop production due to the growing population in the world is necessitating a rapid expansion of irrigated agriculture throughout the world (Awulachew et al., 2005). Limited water and high level of competition, most irrigators in Ethiopia, especially at tail of a scheme, allocation of irrigation water to the field is below the maximum crop water requirement for maximum yield (Lorite et al., 2007). In order to overcome the deficit in water required for crop production and minimize the impact of drought on crop performances, supplemental water has to be supplied in the form of irrigation. With irrigation, it is not only possible to avoid risk in production but also possible to grow multiple crops in a year which helps in food and nutritional security strategies. But, the question is which type of irrigation technology should be employed, from the three broad categories of irrigation: surface (flood, basin, border, and furrows), sprinkler, and drip (micro-irrigation) methods based on application of water in the field. Among the above methods, sprinkler and drip irrigation methods are known to be efficient in maximizing water utilization, but their initial investment cost is often prohibitive and not affordable by the majority of smallholders' farmers. Under such circumstances, less precise and yet least capital-intensive irrigation systems have to be considered. In this relation, furrow irrigation method is the most widely used in Ethiopia in almost all-large and small irrigation schemes. It has been reported by FAO (2001) that 97.8% of irrigation in Ethiopia is done by surface methods of irrigation especially by furrow system in farmer's fields and majority of the commercial farms. Furrows are particularly suitable for irrigating row crops such as vegetables, cotton, sugar beet, maize, tomatoes and potatoes planted on raised beds, which are subject to injury if water covers the crown or stems of the plants (Michael, 2008).

Conventional furrow irrigation (CFI) usually causes excessive deep percolation at the upper part of the furrow, insufficient irrigation at the lower part and considerable runoff, resulting in low application efficiencies and distribution uniformities. Proper furrow irrigation practices can minimize water application and irrigation costs, save water, control soil salinity build up and result in higher crop yields (Michael, 2008).

The development towards optimum utilization of irrigation is to irrigate alternate furrows during each irrigation time (Zhang et al., 2000). By irrigating alternative furrows, half of root is exposed to wet soil condition and the other half is exposed to dry soil condition. A drier soil condition stimulates the creation of phytohormone known as Abscisic Acid (ABA) in shoots. ABA is a primary regulator of the stomatal aperture in water stressed plants. It is presumed that irrigating alternative furrows can help to save irrigation water both by minimizing evaporative loss from plant leaf due to reduced stomatal opening with absence of visible leaf water deficit and by reducing deep percolation losses at the same time (Devlin and Witham, 1986).

Kang et al. (2000) evaluated the alternate furrow irrigation (AFI), fixed furrow irrigation (FFI) and conventional furrow irrigation (CFI) with different irrigation amounts for maize production. They reported that yield reduction in AFI was not significant unlike FFI. Mohajer et al. (2004) investigated application of the saline water in furrow irrigation systems for cotton and maize productions. Water productivity in the alternate furrow irrigation was greater than that in conventional furrow irrigation. Horst et al. (2007) applied surge flow to alternate furrows in cotton fields. The performance of alternate furrow irrigation considerably increased and provided the highest water productivity (0.61 kg/m$^3$) and irrigation application efficiency (85%) as compared to the conventional furrow irrigation. Alternate furrow irrigation also increased water use efficiency in wheat-cotton rotation in Punjab, India (Thind et al., 2010). Moreover, application of the alternate furrow irrigation increased water productivity rather than conventional furrow irrigation in sugarcane fields in southern part of Iran (Sheyni et al. 2009).

Different works have been done on irrigation water management and application of mulch for potato in different part of the world. The results revealed that potato tuber yield increases with increase in irrigation level that leads to avoid drought stress. Kahlon and khera (2015) reported that highest mean tuber yield of potato achieved at higher irrigation level with paddy straw mulching of 6t/ha under drip irrigation condition. Moreover, similar improvement was also reported on biomass yield and irrigation water productivity of potato (Kahlon and Khera, 2015). Though potato has a high water requirement for obtaining good yield, excess irrigation could reduce crop yield and increases production costs beyond increasing the competition for scarce water resource. Therefore, this field experiment was conducted with the objectives to select most effective water saving techniques and improve water productivity of irrigated potato.

## MATERIALS AND METHODS

### Description of the Study Area

The study was conducted at Kulumsa Agricultural Research Center, Tiyo district of Arsi Zone Oromia regional state, Ethiopia. The study area lies between 8°00'59'' N latitude, 39°09'25'' E longitude and situated to an elevation 2200m.a.s.l. It is characterized by Uni-modal rainfall pattern with mean annual rainfall of 809.15mm. The climate of the study area is described with minimum and maximum air temperature of 9.90 $^0$C and 23.08$^0$C, respectively. The soil is a clay loam type, at the experimental site it has a field capacity of 33.60%, wilting point of 21.8 % and the total available water was about 11.80% while, the bulk density is 1.25 g/cm. The

**Table 1:** Long Term Climatic Data of Kulumsa Agricultural Research Center (KARC) (1979-2009)

| Year | RF (mm) | T Max (°c) | T Min (°c) | RH (%) | WS (m/s) | SS (hr) | ETo (mm) |
|---|---|---|---|---|---|---|---|
| Jan | 17.09 | 23.36 | 8.21 | 56.49 | 4.96 | 8.18 | 191.36 |
| Feb | 37.66 | 24.37 | 9.35 | 52.89 | 5.23 | 8.35 | 173.18 |
| Mar | 79.53 | 25.07 | 10.33 | 50.73 | 4.36 | 7.65 | 182.63 |
| Apr | 84.15 | 24.41 | 11.50 | 58.35 | 4.18 | 7.23 | 161.08 |
| May | 88.13 | 24.80 | 11.16 | 57.26 | 4.74 | 7.28 | 179.89 |
| Jun | 87.04 | 23.50 | 10.64 | 80.58 | 4.71 | 6.53 | 133.03 |
| Jul | 124.22 | 21.16 | 10.64 | 76.41 | 4.84 | 4.94 | 128.55 |
| Aug | 131.07 | 20.94 | 10.38 | 77.37 | 3.87 | 4.96 | 105.58 |
| Sep | 97.86 | 21.51 | 9.94 | 75.38 | 2.87 | 5.57 | 99.01 |
| Oct | 42.09 | 22.75 | 10.17 | 60.91 | 4.98 | 7.65 | 192.32 |
| Nov | 10.16 | 22.56 | 8.70 | 53.98 | 5.71 | 8.75 | 198.98 |
| Dec | 10.15 | 22.53 | 7.71 | 54.23 | 6.11 | 9.00 | 179.27 |
| **Total** | **809.15** | | | | | | **1924.87** |
| **Average** | | **23.08** | **9.90** | **62.88** | **4.71** | **7.17** | |

**Source:** KARC Meteorological Station

summarized climate information of the study area is shown in the Table 1.

### Experimental Design and Procedure

The experiment was done in a split plot design with three irrigation water application methods: fixed furrow irrigation (FFI), alternate furrow irrigation (AFI) and conventional furrow irrigation (CFI) method in main plot and two mulch types (straw and plastic) and control as no mulch. Each main plot factors (furrow irrigation methods) was assigned randomly within each replication and every sub plot factor (mulching) was randomly assigned inside each main plots. Sub plot size of 4.0 m x 4.0 m which consists of 4 ridges spaced at 75 cm was used for mulching factor. Main plot consists of three subplots as furrow irrigation water management method. Transparent plastic mulch and wheat straw mulch with a rate of 6 t/ha were used as mulching types in the sub plots. Potato variety was sown in 30 cm intra raw with ridge spaced 75 cm after the land preparation. Each plots were fertilized with 206 kg/ha DAP and 150 kg/ha Urea which is blanket recommendation for potato in the study area. Half dose of urea and full dose of DAP were applied during planting, whereas the rest half dose of Urea was applied at knee height level of potato.

The amount of irrigation water applied was calculated using CROP WAT 8.0 software by using necessary input data (crop, soil and long term climatic data). Irrigation water was applied up to field capacity by monitoring soil moisture content using gravimetric method in the conventional furrow plot. The calculated irrigation depth based on the water holding capacity of the soil in the management allowable depletion level was measured using Parshall flume before diverted to each sub plots.

### Data Collection and Analysis

Potato yield and yield components that includes plant height, number of tuber per plant, tuber and biological yield. Plant height was measure at maturity. Aboveground biomass and tuber yield was collected from all row plots except the border rows and measured directly after harvest. Estimation of water productivity was carried out as a ratio of total bulb yield to the total water applied (Central Statistics, 2011). Water productivity was calculated using the following formula.

$$\text{Water Productivity}\left(\frac{\text{kg}}{\text{m3}}\right) = \frac{\text{Total Bulb Yield(kg)}}{\text{Crop Water Use (m3)}}$$

The collected data were analyzed using statistical analysis system (SAS) version 9.0 procedure of general linear model for the variance analysis. Mean comparisons were carried out to estimate the differences between treatments using Fisher's least significant difference (LSD) at 5% probability level.

## RESULT AND DISCUSSION

### Plant Height

The analysis of variance revealed that different furrow irrigation water management techniques, mulch type and interaction effect of irrigation method and mulch type had not significantly affected plant height at $p>0.05$. Despite no statistical difference, the observed plant height ranges from 76.7 to 80.9cm under different furrow irrigation water application techniques and form 77.3 to 81.7cm under different mulch type (Table 2). Admasu et al (2016)

**Table 2:** Effect of Integrated Mulching and Furrow Irrigation Methods on Potato Yield

| Treatments | TY (kg/ha) | ABY (kg/ha) | PH (cm) | WP ($kg/m^3$) |
|---|---|---|---|---|
| **AFI** (Alternate Furrow) | $40,352^b$ | 11,600 | 75.98 | 19.02a |
| **FFI** (Fixed Furrow) | $39,782^b$ | 12,637 | 78.64 | $18.75^a$ |
| **CFI** (Conventional Furrow) | 44,866a | 12,908 | 78.71 | $10.57^b$ |
| **SM** (Straw Mulch | $44,136^a$ | $13,685^a$ | 76.11 | $16.84^a$ |
| **PM** (Plastic Mulch) | $39,218^b$ | $11,457^b$ | 79.89 | $15.22^b$ |
| **NM** (No Mulch) | $41,646^{ab}$ | $12,003^b$ | 77.33 | $16.28^a$ |
| **CV (%)** | **5.53** | **12.37** | **9.06** | **6.07** |
| **$LSD_{0.05}$** | **2,506** | **1,665** | **ns** | **0.97** |
| **REP** | 2965.41* | 74.60ns | 175.37* | 5.95* |
| **IM MS** | 6984.41** | 428.92ns | 21.88ns | 207.25** |
| **MT MS** | 5441.32** | 1213.18* | 33.44ns | 6.04* |
| **IMxMT MS** | 2000.75* | 115.72ns | 7.74ns | 1.95ns |

**Note:** TY= Tuber yield, ABY= Aboveground Biological Yield, PH= Plant Hieght, WP= Water Productivity, CV= Coefficient of Variation, LSD= Least Significant Difference, REP= Replication, IM= Irrigation Method, MS= Mean Square and MT= Mulch Type

reported that on his study of optimal irrigation regimes and NP fertilizer rate for potato, plant height doesn't show significant difference due to moisture depletion level treatments. In contrary to this study, Dash *et al*. (2018) on potato, Elias *et al*. (2017) on maize and Farrag *et al*. (2016) on tomato revealed that plant height was significantly affected under different irrigation levels and mulch.

## Potato Tuber Yield

The analysis of variance of combined over years data revealed that, different types of irrigation method highly significantly ($p<0.01$) affected potato tuber yield at Kulumsa. Moreover, potato tuber yield highly significantly ($p<0.01$) influenced due to different mulch types used (Table 2). In addition to this, the interaction effect of the two factors, furrow irrigation methods and mulch types, had a significant ($p<0.05$) effect on tuber yield of potato (Table 2).

The highest tuber yield of 44,866 kg/ha was obtained at conventional furrow irrigation method. The maximum tuber yield obtained at conventional furrow irrigation methods is statistically significant to both alternate and fixed furrow method. On the other hand, the minimum tuber yield of 39,782 kg/ha was obtained at fixed furrow irrigation method which is statistically similar with the tuber yield obtained at alternate furrow method. In addition to this, maximum tuber yield of 44,136kg/ha was obtained under straw mulch application. However, the maximum tuber yield obtained at straw was statistically similar with that of no mulch. The minimum tuber yield of 39,218 kg/ha was obtained at plastic mulch condition which was statistically similar with no mulch condition (Table 2). The interaction effect showed that higher tuber yield of 50,452 kg/ha was obtained at conventional furrow irrigation water application technique under straw mulching. Under deficit treatments, the higher tuber yield of 41,942 kg/ha was obtained at alternate furrow irrigation under straw mulch (Table 3).

According to Dash *et al*. (2018) frequent irrigation that avoids drought stress on potato leads to higher tuber yield. Moreover, application of straw mulch improved tuber yield of potato. Moreover, similar finding were also reported on tomato yield that yield was enhanced under straw mulch as compared to the plastic mulch and irrigation increased yield with a straw mulch (Tindall *et al*., 1991). This might be due to enhancement in infiltration rate and soil temperature adjustment due to straw mulch than the plastic mulch that leads to high soil temperature. Kahlon and khera (2015) reported that highest mean tuber yield of potato achieved at higher irrigation level with paddy straw mulching at 6 t/ha under drip irrigation condition. Collin W.B. 1976 also reported that, continuation of black and white plastic mulching after emergence was shown to be disadvantageous.

On the other hand, application of plastic and grass mulching was also reported to enhance emergence, growth rate and yield of potato crop over no mulching (Mahmood *et al*., 2002). Farrag *et al*. (2016) reported that higher irrigation level and application of mulching improved potato tuber yield as compared with the deficit treatments and without mulch. Moreover, application of straw mulch leads to higher tuber yield and biomass than application of transparent plastic.

## Aboveground Biomass Yield

The analysis of variance of combined over years data revealed that, different types of irrigation method had no

**Table 3:** Interaction Effect of Mulch Type with Furrow Irrigation Method

| Mulch Type | Irrigation Method | PH (cm) | | TY (kg/ha) | | ABY (kg/ha) | | WP (kg/m$^3$) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev |
| **SM** | **AFI** | 74.67 | 7.05 | 41,942 | 1,902 | 12,422 | 2,263 | 19.76 | 0.89 |
| **SM** | **CFI** | 78.60 | 1.71 | 50,452 | 3,055 | 15,029 | 1,948 | 11.89 | 0.72 |
| **SM** | **FFI** | 75.07 | 8.41 | 40,013 | 713 | 13,604 | 1,198 | 18.86 | 0.33 |
| **PM** | **AFI** | 78.13 | 6.44 | 37,277 | 2,592 | 10,921 | 1,942 | 18.03 | 0.56 |
| **PM** | **CFI** | 79.47 | 7.25 | 41,489 | 1,814 | 11,645 | 1,939 | 9.78 | 0.43 |
| **PM** | **FFI** | 82.07 | 1.80 | 38,889 | 3,689 | 11,806 | 794 | 19.03 | 0.55 |
| **NM** | **AFI** | 75.13 | 5.77 | 41,836 | 2,866 | 11,458 | 1,111 | 19.72 | 1.35 |
| **NM** | **CFI** | 78.07 | 6.11 | 42,659 | 2,284 | 12,050 | 2,477 | 10.05 | 0.54 |
| **NM** | **FFI** | 78.80 | 20.42 | 40,443 | 5,068 | 12,502 | 2,490 | 19.06 | 2.39 |

significantly ($p>0.05$) difference and mulch types had significantly influence on aboveground biomass production of potato at the study area. Moreover, the interaction effect of irrigation method and mulch types had no significant difference at $p<0.05$. Despite no statistical difference between different types of irrigation method, the observed aboveground biomass ranged from 11,600 to 12,908kg/ha under different furrow irrigation water application techniques and the mulch types recorded minimum and maximum values of 11,457 and 13,685 kg/ha under different mulch type, respectively (Table 2). However, the current finding is in conflict with former reports that revealed aboveground biomass production improved due to high irrigation than under deficit and under mulch than no mulch for potato and other different crops. Farrag *et al*. (2016) reported that highest vegetative yield of potato was obtained when 100% irrigation water requirement of potato applied and when black plastic used as mulch. Others also reported that improvement on potato biomass yield was observed at higher irrigation levels and with paddy straw mulching at 6 t/ha under drip irrigation condition (Kahlon and Khera, 2015).

**Water Productivity**

The analysis of variance for the average of four year data revealed that, different types of irrigation method significantly ($p<0.05$) affected water productivity of potato. Moreover, potato tuber yield was highly significantly ($p<0.01$) influenced due to different irrigation types used (Table 2). In addition to this, the interaction effect of the two factors, furrow irrigation methods and mulch types, had significant ($p<0.05$) effect on water productivity of potato (Table 2).

The highest water productivity of 19.02kg/m$^3$ was obtained at alternate furrow irrigation method. The maximum water productivity obtained at alternate furrow irrigation methods is statistically similar with fixed furrow irrigation method. On the other hand, the minimum water productive of 10.57 kg/m$^3$ was obtained at conventional furrow irrigation method which is statistically inferior to both alternate and fixed furrow method (Table 2).

The interaction effect showed that higher WP of 19.76 kg/m3 was obtained at AFI water application technique under straw mulching (Table 3).The result is in line with the finding of former report in potato and other plants with similar research. According to Dash et al. (2018) frequent irrigation that avoids drought stress on potato leads to higher tuber yield and lower water use efficiency. However, the maximum water productivity was at low irrigation frequency. On the other hand, the maximum water productive was obtained at straw mulching. This is in line with the finding of Kahlon and khera (2015) reported that highest water productivity of potato achieved when paddy straw mulching at 6t/ha used under drip irrigation condition. Similar finding was also reported on maize that water productivity was higher under alternate furrow irrigation method (Elias et al., 2018).

However, the current finding is in conflict with the findings of Farrag *et al*. (2016) who reported that maximum water productivity obtained when higher irrigation level of 100% irrigation requirement of potato combined with black plastic mulching. Similar findings also reported for different crops that highest water productivity was reported in plastic mulch than straw mulch. For example, Elias *et al*. (2018) reported that maximum water productivity of maize was at plastic mulching compared to straw and no mulch conditions. This might be due to plastic mulching increased soil temperature around the root which create unfavorable environment for tuber production in potato (Ren *et al*., 2017).

## CONCLUSION AND RECOMMENDATION

Potato has a high water requirement for obtaining good yield. However, excess irrigation could reduce crop yield and increases production costs beyond increasing the competition for scarce water resource. Better yield was achieved at conventional furrow irrigation methods. However, water productivity was affected due to higher irrigation water application. Moreover, application of straw mulching leads to higher tuber production and water use efficiency. In addition to this, the interaction effect of the two factors, furrow irrigation methods and mulch types, influenced tuber yield of potato in which the maximum was obtained when potato irrigated with conventional furrow irrigation method and straw mulching is used. On the other hand, water productivity was maximized when alternate furrow irrigation used with straw mulching. Therefore, for maximizing tuber yield production of potato under no water stress scenario, irrigation should be done with conventional furrow irrigation methods with straw mulching. On the other hand, under limiting irrigation water resource condition, irrigation of potato could be done with alternate furrow irrigation method with straw mulch for maximizing water productivity of potato at Kulumsa and similar agro-ecology and soil type.

## ACKNOWLEDGEMENT

The authors are grateful to Natural Resource Management Research Directorate, Ethiopian Institute of Agricultural Research, for providing funds for the experiment. They are also thankful Mengistu Mulushewa, Dawit Tedecha and Alemayehu Wolde for their support and technical assistance in the field experimentation.

## REFERENCES

Admasu W, Tadesse K, Hordofa T, Deresse Y, Habte D (2016). Determining of Optimal Irrigation Regimes and NP Fertilizer Rate for Potato (Solanum tuberosum L.) at Kulumsa, Arsi Zone, Ethiopia. Acad. J. Agric. Res. 4(6): 326-332.

Awulachew, S.B., Merrey, D.J., Kamara, A.B., Van Koopen, B., De Vries, F. P. and Boelle, E. 2005. Experiences and Opportunities for Promoting Small-Scale/Micro Irrigation and Rainwater Harvesting for Food Security in Ethiopia. IWMI. Working Paper 98, 2005.

Bos, M. G., Kselik, R. A. L., Allen, R. G. and Molden, D. J. 2008. Water requirements for irrigation and the environment. Springer, Dordrecht, Netherlands.

Collins, W. B. 1976. Effects of mulches on emergence and yield of potatoes. Can. J. Plant Sci. 56: 877-880.

Dash, S.N., Pushpavathi, Y. and Behera, S. 2018. Effect of Irrigation and Mulching on Growth, Yield and Water Use Efficiency of Potato. Int.J.Curr.Microbiol. App.Sci. 7(2): 2582-2587.

Devlin, R. M. and F. H. Witham. 1986. Plant Physiology 4th edition. University of Messochustts and Pennsylvania state university.

Elias Meskelu, Henok Tesfaye, Ayele Debebe and Mulugeta Mohammed. 2018. Integrated Effect of Mulching and Furrow Methods on Maize Yield and Water Productivity at Koka, Ethiopia. Irrigat Drainage Sys Eng 7 (1): 1 – 7.

FAO (Food and Agriculture Organization). 2001. AQUASTAT-FAO's Information systems on water and agriculture. Http://www. wcainfonet.org/cds_static/en/quastat_fao_information_ system_water_ethiopia_en_569_14 36 (online 3/24/05).

FAO (Food and Agriculture Organization). 2002. Deficit irrigation practice. Water Reports Paper No.22. FAO, Rome, Italy.

FAO (Food and Agriculture Organization). 2011. The State of the world's land and water resources for food and agriculture. Managing systems at risk. FAO, Rome, Italy.

Farrag, K., Abdrabbo, M.A.A. and Hegab, S.A.M. 2016. Growth and Productivity of Potato under Different Irrigation Levels and Mulch Types in the North West of the Nile Delta, Egypt. Middle East Journal of Applied sciences. 6(4): 774 – 786.

Horst, M.G., S.S. Shamutalo, J.M. Goncalves, L.S. Pereira. 2007. Assessing impacts of surge-flow irrigation on water saving and productivity of cotton. Agricultural water management 87:115-127.

Kahlon, M.S. and Khera, K.L. 2015. Irrigation Water Productivity and Potato (Solanum tuberosum L.) Yield in Different Planting Methods under Mulch Conditions. Journal of Agriculture and Ecology Research International. 3(3): 107-112.

Kang S., Lianga Z., Panb Y., Shic P., Zhangd J. 2000. Alternate furrow irrigation for maize production in an arid area. Agricultural Water Management, 45:267-274.

Lorite, I.J, Mateos L., Orgaz F., Fresses E. 2007. Assessing deficit irrigation strategies at the level of an irrigation district. Agricultural Water Management 91:51-60. http://dx.doi.org/ 10.1016/ j.Agwat. 2007.04.005.

Mahmood, M.M., Farooq, K., Hussain, A. and Sher, R. 2002. Effect of mulching on growth and yield of potato crop. Asian journal of plant science. 1(2): 132 – 133.

Michael, A.M. 2008. Irrigation Theory and Practice. 2nd edition. Jupiter Offset Printers, Dehli-32. 568p.

Mohajer Milani P., Mollahosseini H., Nouri H.S.M. 2004. Increasing irrigation productivity with saline water in alternate furrow irrigation for maize and cotton. Iranian Journal of Soil and Water Sciences, 18(2):202-208 (in Persian).

Pereira, L.S., Cordery, I. and Iacovides, I. 2009. Coping with water scarcity: Addressing the challenges. Springer Science+Business Media B.V. Paris, France.

Ren, X., Chen, X., Cai, T., Wei, T., Wu, Y., Ali, S., Zhang, P. and Jia, Z. 2017. Effects of Ridge-Furrow System Combined with Different Degradable Mulching Materials on Soil Water Conservation and Crop Production in Semi-Humid Areas of China. Front. Plant Sci. 8:1877.

Sheyni Dashtgol A., Kashkouli H.A., Naseri A., Boroumandnasab S. 2009. The effects of every- other furrow irrigation on Water Use Efficiency in South Ahvaz sugarcane fields. Journal of Science and Technology of Agriculture and Natural Resources, 49:45-57 (in Persian).

Thind, H.S., Buttar G.S., Aujla M.S. 2010. Yield and water use efficiency of wheat and cotton under alternate furrow and check-basin irrigation with canal and tube well water in Punjab, India. Irrigation Science, 28:489–496.

Tindall, J. A., Beverly, R.B. and Radcliffe. D.E. 1991. Mulch Effect on Soil Properties and Tomato Growth Using Micro-Irrigation. Agron. J. 83:1028-1034.

William J. Lamont Jr., Michael D. Orzolek & Bruce Dye (2008) Production of Drip Irrigated Potatoes as Affected by Plastic Mulches and Row Covers. Published online Pages 39-47

Zhang, J., S. Kang, Z. Liang., Y. Z. Pan, P. Shi, Y. H. Pan, Z. S. Liang, X. T. Hu. 2000. Soil water distribution, uniformity and water use efficiency under alternate furrow irrigation in arid areas. Irrigation Science 19: 181-190.