Science Letters
2016 | Volume 4 | Issue 2 | Pages 118-123

RESEARCH ARTICLE OPEN ACCESS

Impact of Drip and Furrow Irrigation Methods on Yield, Water Productivity and Fertilizer Use Efficiency of Sweet Pepper (*Capsicum annuum* L.) Grown under Plastic Tunnel

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Abstract
High efficiency irrigation offers efficient use of water, labor and other resources and allows the vegetable industry to grow in future. Field studies were conducted for two consecutive years in district Toba Tek Singh to investigate the comparative water use efficiency, fertilizer use efficiency and economics of sweet peppers under drip and furrow irrigation methods. Treatments comprised of T1= irrigation with drip method + 100% fertilizer of recommended dose; T2 = irrigation with drip method + 50% fertilizer of T1; T3= irrigation with furrow method + 100% fertilizer of recommended dose with conventional method and T4 = irrigation with furrow method + 50% fertilizer of T3. Results indicated that yield and yield components were significantly improved under drip irrigation compared to conventional irrigation method. Sweet pepper yield was increased by 60% in drip irrigation system over furrow irrigation method. The resource use efficiency analysis showed that drip irrigation exhibited 47% more relative water use efficiency, 59% higher water productivity and 54.5% more fertilizer use efficiency over furrow irrigation. Overall, drip irrigation saved up to 53.5% volume of water applied to conventional irrigation method in sweet pepper production. The net income of sweet papers was increased by 66% with less water and less fertilizer by adopting high tech drip irrigation technology. Opportunities still exist to increase sweet paper output in the study area by increasing the level of above mentioned productive resources with proper irrigation scheduling. The study also suggested that drip irrigation system has a greater scope for the production of off-season vegetables grown under plastic tunnel especially in water scarce areas of Pakistan.
Keywords Sweet peppers, drip irrigation, conventional irrigation, water productivity, fertilizer use efficiency

Received February 02, 2016 **Accepted** April 18, 2016 **Published** August 15, 2016
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To cite this manuscript: Asif M, Akram MM, Raza MA. Impact of drip and furrow irrigation methods on yield, water productivity and fertilizer use efficiency of sweet pepper (*Capsicum annuum* L.) grown under plastic tunnel. Sci Lett 2016; 4(2):118-123.

Introduction

Vegetable crops are the eminent source of human nutrition and represent a dynamic segment of Pakistan's agriculture. Demand for vegetables is increasing in national and international market. Despite high returns, non-availability of irrigation water is hindering the expansion of area under vegetables [1]. Commercial production of vegetable is not possible without adequate water availability throughout the growing season. Internationally, the water availability is a great challenge and in the present scenario, Pakistan may face an acute shortage of irrigation water. Due to an expected scarcity of water in the future, water use efficient crops can only cope with the increasing demand. Adoption of a more efficient water saving techniques will allow flexibility in planting time, establishing a more uniform crop stand, better quality, higher yield for off season vegetables with existing scarce water resources [2].

Average annual rainfall in Pakistan ranges 254 mm to 356 mm against a potential demand of 1778 mm [3]. It was also reported that water availability for the agriculture will fall from 72% in 2000 to 62% by 2025, globally, and 87% to 73% in developing countries [4]. Kahlown et al. [5] concluded that 13–18 cm of water is applied per irrigation event on an average for a crop in Pakistan against the actual consumptive use of 8 cm of water between two irrigation events. On-farm irrigation efficiencies in Punjab range between 23% and 70% [6]. Rapidly increasing population may put additional pressure on scarce water resources of the country and therefore, food security is challenged by an ever increasing food demand. Thus, the agriculture in Pakistan faces a challenge to produce more food with less water by increasing water productivity.

Effective and efficient water utilization must be paid more especial attention in Pakistan because of its importance and need. Government of Pakistan always gives a top priority to modernize the agriculture sector. A mega project, entitled "Punjab Irrigated Agriculture Productivity Improvement Project" recommended the deployment of hi-tech drip irrigation system for precise farming and achieving vertical growth in crop production with the farmer's participation to promote drip irrigation technology. It includes Hi-tech interventions, i.e., drip and sprinkler irrigation for row crops like vegetables, maize, cotton and orchards. Drip irrigation with its ability to small and frequent applications of water has created interest among the farmers because of less water requirement, less fertilizer use; increased production and better quality produce [7]. Economic evaluation of drip irrigation in off season vegetables (capsicum, tomato, cucumber) and in row crops (maize and cotton) in various districts of Punjab revealed that this system conserves considerable amount of water and results better returns despite higher initial investment. Drip irrigation will open up considerable prospects to develop high value crops, fruit-trees, vegetables and other crops of economic value.

Sweet pepper (*Capsicum annuum* L.) is one of the most important vegetables that are consumed worldwide, after tomatoes and onions [8]. Sweet pepper contribute substantially to the Pakistani diet as it is a good source of vitamins A, B and C. The climate of Punjab is fit for simple unheated plastic tunnels for enclosed vegetable growing which is well-matched for bridging the gap in vegetable markets during cooler months in the market than the yield of the open field. Vegetable crops developed under plastic mulches had presented earlier (7 to 14 days) and enlarged yields (2 to 3 times) over bare soil [9]. With the introduction of drip irrigation system, pepper production in Pakistan not only achieves national needs, but will also aid in getting an overseas exchange but the production of this crop is affected adversely by moisture deficit. Productivity of this crop can be increased by adopting an improved package of practices, particularly *in-situ* moisture conservation by mulching as well as high-tech irrigation especially drip irrigation with appropriate irrigation scheduling.

Numerous experiments have reported the benefits of drip irrigation in several crops, but research is limited on response of sweet paper production under tunnel conditions on a farmer's field. Keeping this in view, the present study was undertaken to study the impact of drip irrigation and fertigation on capsicum crop and to compare the results with the conventional method of growing crops under surface irrigation. This work, therefore, is aimed to calculate crop water requirement, fertilizer and water use efficiency and economics of drip and conventional irrigation methods for sweet peppers to help boost its production within the study area and other similar environments.

Materials and Methods

Description of experimental site

The study was carried out at farmer's site located in Chak No. 246/GB, District Toba Tek Singh, Pakistan during growing season 2013-14 to 2014-15. District Toba Tek Singh is situated at latitude 30^o 58' 07.94" N, and longitude were 72^o 41' 52.29" E with altitude of 149 m. The study site was located in Northern Irrigation Plain according to Agra-ecological Zones of Pakistan. Mean maximum and mean minimum temperatures in summer (April-October) were 49^{o}C and 27^{o}C, respectively, while in winter, the temperature ranges between 6^{o}C and 21^{o}C (November-March). Average normal precipitation was about 350mm. The soil was clay loam with Ece 1.70-1.90 dS/m, pH 7.5-7.8, organic matter 0.0.48-0.61%, Olsen-P 21-22.7 ppm at 0-15 cm and 15-30 cm depth.

Crop husbandry

Nursery of sweet pepper (Orible variety) was grown in trays filled with peat max soil at 30 ^{o}C in day and 12 ^{o}C in night protected from diseases and insects. The experimental area was 3600 m^2 and 42 numbers of beds were made with specially designed bed planter in a leveled experimental field. The 14 plastic tunnel of 60 × 3.2 × 2.134 m were erected and black polythene mulch was used. Each tunnel has three beds covered with plastic sheet. Sweet pepper seedlings of 25 days were transplanted in double row planting geometry (Fig. 1) with plant to plant distance 35 cm and row to row distance 30 cm on each bed during 1st week of October in 2013-14 and 2014-15. Recommended dose of fertilizer (187-50-50 NPK kg/acre) was applied to crop. Plant protection measures were adopted to avoid insect and disease attacks as and when needed. Crop was harvested by 15 May each year.

Experimental design and treatments

The experiment was laid out in randomized complete block design having four treatments replicated thrice. The treatments were as follows: T_1 = irrigation with drip method+100% recommended dose of fertilizer (Rd) through drip irrigation; T_2 = irrigation with drip method + 50% recommended dose of fertilizer through drip irrigation; T_3 = irrigation with furrow method +100% recommended dose of fertilizer with conventional method and T_4 = irrigation with furrow method + 50% recommended dose of fertilizer with conventional method. The plants were irrigated with the help of drip and

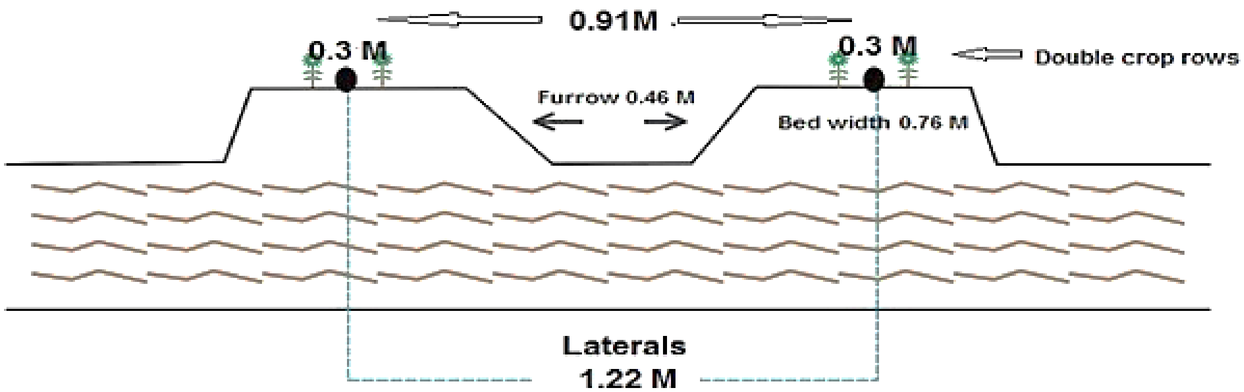

Fig. 1 The scheme of drip irrigation showing plant to plant and row to row distance and placement and distance between drip lines.

furrow (as flood) systems as per requirement. Two grams of each urea, di-ammonium phosphate and potash were applied to each plant of sweet papers at weekly interval with water through drip irrigation while in furrow irrigation, fertilizer was applied at land preparation and broadcasted in between the furrows at flowering and fruiting stages according to conventional practice.

Description of drip irrigation system

The drip irrigation system consisted of a pump, fertilizer venture, gravel filter, disc filters, control valves, pressure gauges and a flow meter. The amount of water applied for drip irrigation was recorded with flow meter and for furrow irrigation by using cut throat flume. In drip irrigation, each treatment (zone) had one valve to control water application. The lateral lines of 16 mm diameter LLDPE pipes were laid along the crop rows and each lateral served two rows of the crop with emitters of flow rate 2.30 LPH spaced at 0.3 m along the drip line. The UPVC pipes of 90 mm diameter were used for main and 40 mm diameter was used for sub-main. The main line was directly connected to a 16 HP diesel engine installed to lift water from the pond.

Crop water requirements

The CROPWAT 4 window's version 4.2 model was used to calculate crop water requirements for sweet pepper by combining different climatic, crop and soil data. The CROPWAT uses Penman-Monteith equation for the calculation of reference evapotranspiration. The seasonal Crop Water Requirement (CWR) called as actual evapotranspiration was calculated by multiplying the reference evapotranspiration with crop coefficient (K_c) for capsicum. The climatic data included minimum and maximum temperature (^oC), relative humidity, daily sunshine hours, wind speed and rainfall is required by CROPWAT computer model for the calculation of crop water requirements. The daily climatic data was recorded from Regional Meteorological Centre, for the Meteorological Observatory, Ayub Agricultural Research Institute, Faisalabad located at a distance of 45 km from the study area.

Data collection and analysis

Data regarding yield and yield components, total water used per hectare, number of irrigations, water used per irrigation, and total yield (kg/ha) were recorded. Benefit-cost ratio was calculated for treatment T1 and T3 by considering various inputs used in drip irrigation system and surface irrigation during cultivation. Water productivity, water use efficiency and fertilizer use efficiency of each irrigation system was calculated using the following equations:

Water use efficiency (WUE) (kg/ha/mm) = CY / ET_c

Where

CY = Crop yield (kg/ha)

ET_c = Crop evapotranspiration

Water productivity (WP) (kg/m^3) = CY / CW

Where

CY = Crop Yield (kg/ha)

CW = Consumed water (m^3/ha)

Fertilizer use efficiency (FUE) = CY / CF

Where

CY = Crop yield (kg/ha)

CF= Consumed fertilizer (kg/ha) [10]

Benefit-cost ratio (BCR) = Total revenue / Total cost

Statistical analysis

One-way analysis of variance (ANOVA) was used for the evaluation of treatments significance and

Duncan's multiple-range test was used to evaluate differences among treatments at P=0.05 using MSTAT statistical package [11].

Results and Discussion

The results of yield and yield components like plant height, fruit number per plant and the fruit yield per plant for two years pooled data are given in Table 1. Results indicated that, yield and yield attributing characters were significantly improved under treatment T1 (irrigation with drip method + fertigation) as compared to the other treatments. The height of plant under treatment T1 (93.95 cm) was found significantly superior over other treatments. Overall, drip irrigation exhibited 50 % higher plant height over surface irrigation with conventional method of fertigation. As regards to fruit yield per plant, maximum yield was recorded in treatment T1 (6.25 kg) followed by treatment T2 (4.5 kg) and the lowest value was recorded in treatment T4 (2.4 kg). All the yield attributing characters were found to be significantly higher under drip irrigation treatments (T1 and T2) than surface irrigation methods. The treatment T1 recorded 49% and 28% higher number of fruits per plant as compared to T3 and T4, respectively. Drip irrigation was observed to have a significant effect on yield attributing characters than furrow irrigated treatments. The higher vegetative growth in treatment T1 might be attributed to the optimum availability of soil moisture as well as plant nutrients in the soil [12, 13]. The poor vegetative growth in T3 and T4 might be due to moisture stress caused by unfavorable moisture conditions due to higher percolation losses under surface irrigation [14, 15]. Drip irrigation might have supplied water and nutrients in adequate proportion throughout the growing period of crop which triggered the plant growth through accumulation of higher photosynthates in the plant leaves resulting more vegetative growth [16].

The drip irrigation with 100% fertilizer application through drip irrigation significantly increased the yield of sweet papers as compared to furrow irrigation with conventional method of fertigation (Table 1). Among various treatments, the highest yield (50.9 t/ha) was recorded under treatment T1 which was 60% higher than surface irrigation. The lower yield obtained under furrow irrigation method (20.6 t/ha) might be attributed to water stress during the critical growth period, coupled with less availability of plant nutrients due to excessive leaching of plant nutrients in furrow application. Another reason of low yield under surface irrigation might be poor aeration and higher weed infestation problems under furrow irrigation [17]. These results confirm the findings of previous reports [18, 19]. Drip irrigation delivers water and nutrients at a low rate, according to the requirements of the plants at frequent intervals in the crop root zone, which increases the availability of nutrients compared to the conventional method of irrigation. More nutrient availability, especially near the root zone might have increased the translocation of photosynthates to the storage organ of sweet papers resulting in an increased weight of sweet papers [20].

It is quite evident from the data presented in Table 1 that drip irrigation treatments (T1, T2) exhibited higher fertilizer use efficiency during both the study years compared to furrow irrigation treatments (T3 and T4), where irrigation method and fertigation was conventional. This higher fertilizer use efficiency (FUE) in drip irrigation treatments might be due to the reasons that fertilizer fixation was delayed when fertilizer applied with drip irrigation and plants absorbed nutrient more quickly and directly from the soil solution. In addition, the positive effect of fertigation was enhanced due to optimum soil moisture content in the soil, which facilitated maximum utilization of applied nutrients to crops [21]. In the present study, fertigation enhanced the availability of NPK in the moist soil regime, where the roots of sweet papers plant are located and proved to be the most consistent method of increasing yield across the two years of study. These results are quite in line with the previous findings of [22], who recorded significantly highest crop yield, P-uptake, P-recovery and agronomic efficiency with drip fertigation while the lowest was determined by broadcast method.

The crop water requirement and irrigation requirement were calculated by using CROPWAT model. The reference evapotranspiration (ETo) was gradually increased from January to June and then began to drop gradually till December for the study area (data not shown). The peak value of ETo was noted in June as 7.1. The crop water requirement (CRW) calculation revealed that CWR was estimated as 710.2 mm per 10 days while effective rainfall was 147.9 mm per 10 days. By using CROPWAT model, the irrigation water requirement (IWR) was estimated 562 mm for conventional methods of irrigation while IWR under drip irrigation system was calculated as 262 mm (data not shown). The peak value of IWR was noticed in May as 7.16 mm/day and the minimum value was determined in November 0.76 mm/day (data not shown).

Table 1 Yield and yield components, water productivity, water use efficiency and fertilizer use efficiency of sweet pepper as influenced by different treatments (average data of two years).

Treatments	Plant height (cm)	Fruits/plant	Fruit yield plant (kg)	Yield (t/ha)	Water productivity (kg/m^3)	WUE (kg/ha/mm)	FUE (%)
T1	93.95a	8.9a	6.25a	50.936a	10.725a	88a	54.45a
T2	76.4b	7.3b	4.5b	38.150b	8.035b	75.5b	46.1ab
T3	63.6c	5.36c	3.1c	34.595b	7.285b	63.0c	36b
T4	50.4d	4.5d	2.4d	20.600c	4.340c	49.5d	20.7c
LSD	6.30	0.39	0.81	5.46	1.14	10.05	12.16

Means followed by different letters in a column are significantly different at P=0.05.WUE = water use efficiency; FUE = fertilizer use efficiency

Thus, the irrigation water requirement under drip irrigation system for sweet paper was calculated as 262 mm that resulted the highest yield with highest water productivity (10.72 kg/m^3) and water use efficiency (88 kg/ha/mm) under treatment T1 as compared to lowest yield with lowest water productivity (4.3 kg/m^3) and low water use efficiency (49.5 kg/ha/mm) under surface irrigation. The study revealed that 292 mm of water was sufficient to grow one hectare of sweet pepper with drip irrigation system in a semi - arid climate of Pakistan.

Table 2 Economic analysis of drip and furrow irrigation for sweet peppers.

Activity	Furrow irrigation ($/ha)	Drip irrigation ($/ha)
Transportation	235.0	328.51
Labor	7.41	3.70
Tunnel expenditures	1778.4	1778.40
Total Fixed Cost	2020.8	2111.0
Land preparation	161.0	171.0
Seed	138.3	138.3
Fertilizer	971.0	394.0
Pesticides/insecticides	133.4	89.0
Irrigation	200.1	122.26
Total variable cost	1603.8	915.00
Total cost	3625.0	3026.0
Total income	4940.00	7163.0
Net return	1315.4	4137.0
Benefit cost ratio	1.36	2.37

Therefore, the study revealed that even if 53% less quantity of water is supplied through drip irrigation (T3), 32% higher yield of sweet paper was established as compared to surface irrigation. These results confirm the findings of Paul et al. [23], who reported higher crop yield and water-productivity under drip irrigation due to the continuous supply of water in required quantity at the right time without flooding to cause hypoxia. Therefore, the roots remain well aerated due to delivery of water and nutrients directly to the plant roots that improved plant vigor [24]. The beneficial effect of drip irrigation in onion and hot papers was also reported earlier by Igbadun et al. [25].

Highest net income of 4137 $/ha with BCR of 2.37 was recorded in drip irrigation treatment T1 while the lowest net income of 1315.4 $/ha with a Benefit Cost Ratio (BCR) of 1.36 was recorded in furrow irrigation treatment T3 (Table 2). It is quite evident that, the drip irrigated treatments coupled with fertigation gave better net return per hectare than their corresponding treatments with conventional irrigation method. Similarly, higher BCR ratios were obtained in treatments with drip irrigation as compared with corresponding furrow irrigation treatments. Similar trends have been reported in net income by Tagar et al. [18]. The BCR of 1.38 in conventional furrow irrigation method was due to comparatively lower system cost and greater losses of fertilizer. However, the net profit in all drip irrigated treatments was observed to be high as compared to furrow irrigation. Similar results have been reported by Gadissa and Chemeda [26] and Qureshi et al. [27].

Conclusions

Drip irrigation significantly improved the crop yield and quality of sweet pepper with considerable reduction in costs of water, energy, labor and chemical inputs. Water productivity was considerably enhanced due to less water consumption and higher water use efficiency under drip irrigation. Fertigation through drip irrigation was found most appropriate and profitable practice compared to furrow irrigation method. It was also concluded that, drip irrigation system coupled with fertigation could increase sweet paper yield up to an extent of 60% over surface irrigation with less quantity of water. Famers with scarce water resources can enjoy significant water and capital investment savings using drip irrigation due to improved profitability which suggested that drip irrigation system has a greater scope for the production of off-season vegetables grown under plastic tunnel especially in water scarce areas of Pakistan.

References

[1] Iqbal M1, Sahi FH, Hussain T, Aadal NK, Azeem MT, Tariq M. Evaluation of comparative water use efficiency of furrow and drip irrigation systems for off-season vegetables under plastic tunnel. Intl J Agri Crop Sci 2014; 7:185-190.

[2] Ismail MR, Puteri EM, Abdullah SN, Berahim Z, Bakhtiar R, Kausar H. Growth, Yield and water use efficiency response of tunnel grown hot pepper under deficit irrigation. Agri Water Manag 2015; 32:134-167.

[3] Khan SRA. Water resource development potential: Pakistan water gateway 2003. (Available online with updates at www.waterinfo.net.pk/article_sriaz2.htm).

[4] Ashraf M, Nasir A, Saeed MM. Evaluation of the existing water productivity water productivity in the lower bari doab canal command- a case study. Pak J Agri Sci 2010; 47: 389-397.

[5] Kahlown MA, Raoof A, Hanif M. Plant population effect on paddy yield. J Drain Water Manage 2001; 5:1-5.

[6] Kalwij IM. Assessing the field irrigation performance and alternative management options for basin surface irrigation systems through hydrodynamic modeling. 1997. Report No. 35, International Water Management Institute, Lahore, Pakistan

[7] Shakoor A, Arshad M, Tariq AR, Ahmad I. Evaluating the role of bentonite embedment in controlling infiltration and improve root zone water distribution in coarse soil. Pak J Agri Sci 2012; 49:375-380.

[8] Belel MD. Effects of grassed and synthetic mulching materials on growth and yield of sweet pepper (*Capsicum annuum*) in Mubi, Nigeria. J Agri Soc Sci 2012; 8: 97–99.

[9] Jimenez I, Euan J, Jorden J. Vegetables developed under plastic mulch: Effects of mulching on yield and quality. Agri Water Manag 2014; 92:129-137.

[10] Martin S, Nina KM, Vesna Z, Branka BZ, Marina P. Effect of different fertilization and irrigation practices on yield, nitrogen uptake and fertilizer use efficiency of white cabbage. Sci Horti 2010; 125:103-109.

[11] Steel RGD, Torrie JH, Dickey DA. Principles and procedures of statistics. A biometrical approach, 3rd Ed. McGraw Hill Book Co., New York; 1997, p. 172-177.

[12] Yasemin K, Sahin U, Fatih KM, Selcuk M. Fruit yield and quality and irrigation water use efficiency of summer squash drip-irrigated with different irrigation quantities in a semi-arid agricultural area. J Integ Agri 2014; 13:2518-2526.

[13] Pattanaik SK, Sahu NN, Pradhan PC, Mohanty MK. Response of banana to drip irrigation under different irrigation designs. J Agri Engin 2003; 40:29-34.

[14] Vazquez N, Pardo A, Suso ML, Quemada M. Drainage and nitrate leaching under processing tomato growth with drip irrigation and plastic mulching. J Agri Eco Envirn 2005; 112:313-323.

[15] Antony E, Singandhupe R. Impact of drip and surface irrigation on growth, yield and WUE of capsicum (*Capsicum annum* L.). Agri Water Manag 2003; 65:121–132.

[16] Aujla MS, Thind HS, Buttar GS. Cotton yield and water use efficiency at various levels of water and N through drip irrigation under two methods of planting. Agri Water Manag 2004; 71:167–179.

[17] Kumari R, Kaushal A. Drip fertigation in sweet pepper: A review. Int J Engine Res Appl 2014; 4:144-149.

[18] Tagar A, Chandio FA, Mari IA, Wagan B. Comparative study of drip and furrow Irrigation methods at farmer's field in Umarkot. World Acad Sci Engin Technol 2012; 69:863-867.

[19] Singh A. Economic feasibility of drip irrigated tomato crop under rainfed condition. Agri Engin Today 2007; 31:1-5.

[20] Antony E, Singandhupe R. Impact of drip and surface irrigation on growth, yield and WUE of capsicum (*Capsicum annum* L.). Agri. Water Management 2003; 65:121–132.

[21] Stewart WM, Reiter JS, Krieg DR. Cotton response to multiple applications of Phosphorus fertilizer. Better Crops 2005; 89:18-20.

[22] Shah KH, Aslam M, Memon MY, Siddiqui SH, Imtiaz M, Khan P. A comparison of the efficiency of fertigation technique versus conventional methods of P application in berseem. Pak J Soil Sci 2003; 22: 76-80.

[23] Paul JC, Mishra JN, Pradhan PL, Panigrahi B. Effect of drip and surface irrigation on yield, water use-efficiency and economics of capsicum (*capsicum annum* L.). Eur J Sust Develop 2013; 2: 99-108.

[24] Lingaiah D, Katti GS, Mohammad S. Influence of drip irrigation on crop growth, yield and water use efficiency in cabbage. Int J Agri Sci 2005; 1:110-111.

[25] Igbadun HE, Ramalan AA, Oiganji E. Effects of regulated deficit irrigation and mulch on yield, water use and crop water productivity of onion in Samaru, Nigeria. Agri Water Manag 2012; 109:162-169.

[26] Gadissa T, Chemeda D. Effects of drip irrigation levels and planting methods on yield and yield components of green pepper (*Capsicum annum* L.) in Bako, Ethiopia. Agri Water Manag 2009; 96:1673–1678.

[27] Qureshi AL, Lashari BK, Kori SM, Lashari GA. Hydro-salinity behavior of shallow groundwater Aquifer underlain by salty groundwater in Sindh Pakistan. Fifteenth International water technology conference, IWTC-15 2011, Alexandria, Egypt.