Kurdish Studies
August 2024
Volume: 12, No: 4, pp 1732 - 1736
ISSN: 2051-4883 (Print) | ISSN 2051-4891 (Online)
www.KurdishStudies.net

DOI: 10.53555/ks.v12i4.3615

Sustainable Irrigation System to Decrease Carbon Footprint and Increase Yield of Citrullus Lanatus L.

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Abstract
Water melon (*Citrullus lanatus* L.) is one of the famous summer fruits globally and consumed frequently. The watermelon is getting importance and attention due to the fact that it prevents numerous lethal diseases due to the presence of Vitamin C, Lycopene, and antioxidant activity and has nutritional value as well. The appropriate selection of irrigation method, use of fertilizers and irrigation analysis (Irrigation time start, irrigation time ends, irrigation duration and number of irrigation) etc. assists to minimize the carbon footprint (CFP), and energy footprint (EF) of watermelon. Hence most conventional and extensively used method for the production of watermelon is flood irrigation system. The present study used a life cycle assessment approach in order to assess CFP and EF of watermelon production grown under drip irrigation (DI) and flood irrigation (FI) methods. The results indicated that the total consumption of water by drip and flood systems were 178000 liters and 319815 liters respectively with the yield of 1498.75kg/ ha for drip irrigation system and 1047.75 kg/ ha for flood irrigation. Similarly, the energy footprint of watermelon grown under DI was 494.76 BTU/kg and FI system was recorded 1269.31 BTU/kg. The carbon footprint of watermelon was found less for drip irrigation system (0.0405kgCO_2) as compared to flood irrigation system 0.0726 kgCO_2. It is recommended to use drip irrigation system for the growth of watermelon.

Keywords: Carbon footprint, Drip Irrigation, Energy Footprint, Flood Irrigation, Life Cycle Assessment

1. Introduction

An incomparable state of global warming has been apparent during previous decades. Numerous experts claimed that considerable increase in the levels of carbon dioxide (CO_2) level initiated global warming (GW) and climatic instability (IPCC 1996; Aziz et al. 2021). The consequences and concerns of climate change are sensed on worldwide level in several form such as crop losses, declining ice caps, severe ecological imbalance, upsurge strengths and frequency of floods as well as droughts, changed precipitation distribution, and shifting of weather patterns. These effects lead to economic losses in various perspectives significantly (Stern 2006). Pakistan's irrigation system with its other quality inputs, is important for the food security and livelihood (Government of Pakistan, 2021). The management practices such as water and land are vital components to reduce the burden of water use efficiency of rainfed areas and also to improve the livelihood (Albeyi, et al. 2006; Passioura 2006). The reduction in agricultural productivity and water use efficiency are the uppermost concerns of Government of Pakistan (Yu et al. 2013). The climate change is caused by increased concentration of GHGs. Among different GHGs the six anthropogenic gases (human induced gases) are perfluorocarbon (PFCs), Hydrofluorocarbon (HFCs), Nitrous oxide (N_2O), carbon dioxide CO_2, Sulphur hexafluoride (SF_6), methane (CH_4) **(**Pandey & Agrawal, 2014). Agriculture is an elementary source of GHGs emission, covering nearly 35% of land region accounts for about 50%, 70%and 20% of CH_4, N_2O, and CO_2 correspondingly (Montzka et al. 2011). The term "footprint" was introduced by (Wackernagel & Rees 1996) for the purpose of describing the impacts of activities that are associated with of human production and consumption. In the following methodology they described "ecological footprint "as a secretarial tool utilized in order to assess consumption of resources and waste integration needs of a specific human population /economy in terms of compliant productive land zone. (Global Footprint Network 2007). The concept "carbon footprint" derived from ecological footprint but presently it has been evolved into an idea/concept of its precise right. Usually, a CFP target on those activities such as developments and practices related with the CO_2 emission and remaining GHGs (East 2008). Energy Footprint (EF) referred to the energy applied and utilized during product's entire life cycle in order to manufacture, transport, use, and disposal of the product. Energy footprint is further subdivided into two categories included mechanical energy and electrical energy. Mechanical energy is the energy that is diesel-based energy required for production, transportation and cold storage facility whereas electrical energy is electrical based energy required for the production, transporting and cold storage facility (Patel & Parmar 2015). Nearly, energy usage of 35% with CO_2 emissions of 23% are associated with irrigation (Kendall 2012). The present study aims to assess the yield of water melon (*Citrullus lanatus* L.) grown under two irrigation systems in Quetta District, Balochistan and the release of carbon into the atmosphere.

2. Results and Discussion

2.1. Harvesting, Measurements and Fruit Quality

The significant increase ($p=0.05$) in growth parameters were observed for two irrigation systems. The selected growth parameters were root length (RL), Vine Length (VL), number of vines per plant, number of flowers per plant, leaf index (LI), Leaf Area (LA).

The VL was observed as 244.8 cm in case of DI system and 190.3 cm in case of FI method. Similarly, the number of vines per plant was 7.35 and 5.9 for DI and FI respectively. The average number of flowers and fruits per plant were 8 and 5.2 for DI and 5.6 and 4 for FI system correspondingly. The increase in the length of root and weight of fruit was also observed in plants grown under drip irrigation system. The fruit size was 51.5 diameter in DI system. The vine length and leaf area were observed as 244.8cm and 9.41 cm in case of DI system whereas 190.3cm and 4.84cm in FI system respectively.

A significant effect of irrigation system on the crop yield was observed. The yield was greater as 1498.75 Kg from the field under DI system and less yield of 1047.75 Kg was obtained from the field under FI system.

2.2. Water consumption and yield of watermelon

The total water consumption for watermelon was 178000 (liters) from drip-based system and 319815 (liters) from flood-based system, which indicated that 56% of water was saved in drip system and 44% of water was wasted in flood irrigation system for the growth of water melon. The total yield of watermelon in drip and flood system was 1498.75 Kg/plot and 1075 Kg / plot respectively. Hence it proves that drip irrigation system either saved the substantial quantity of water but also enhanced the yield of watermelon considerably. Similar study was conducted by other researchers to prove that the drip irrigation system is highly efficient to conserve water and increase yield (Singh et al. 2009; Panigrahi et al. 2010; Rashidi, 2011; Bazi et al. 2015; Patel & Parmar 2015; Sahin et al. 2015; Aziz et al. 2021; Zhou et al. 2023).

2.3. Energy Footprint

For irrigation the total energy consumption was 350 (KWh) and 178 (KWh) for FI and DI systems. For transportation and land preparation the energy consumption was 40 (KWh). The watermelons (*Citrullus lanatus* L.) were marketed in three pickings to the market which was nearer to the experimental field. Consequently, the total energy consumption for land preparation, irrigation, and transportation of watermelon in DI and FI system was 218 and 390 (KWh) correspondingly stated in table 3. The EF of water melon grown under DI and FI systems was 494.76 BTU/Kg and 1269.31 BTU/Kg respectively. Similar results for sugarcane crop were reported by (Reddy et al. 2015) and watermelon by (Zhou et al. 2023).

2.4. Carbon Footprint

The water, energy and carbon footprints were calculated by using formula (Patel & Kumar 2013). The pond length was "5m" through which 319815 and 178000 liters of water was abstracted in order to irrigate flood and drip-based fields respectively at "100%" efficiency of pump. The energy consumption of pump for drip and flood irrigation system is 0.024 (KWh) and 0.072 (KWh) respectively. The CFP of water melon for DI and FI system was 0.0405 $KgCO_2$ and 0.0726 $KgCO_2$ respectively as shown in figure 2. Similarly, (Daccache et al. 2014) reported CO_2 emissions for sunflower, cotton, and wheat productions.

3. Materials and Methods

The present field study was conducted at Agriculture Research Vegetable Seed Production (ARVSP) situated at Saryab road Quetta, Balochistan from May 2023 to September 2023 in order to calculate yield, EF and CFP of Water melon (*Citrullus lanatus* L.). Climate of experimental area was dry and the soil was sandy loam to silt loam. The seed samples of Water melon variety WM 777 were obtained from parental institute in order to avoid any sort of insignificance regarding seed genus and species. The design of experiment was randomized complete block designs (RCBD). The Water melon (WM 777) seeds were planted to 5000 square feet plot for drip and flood irrigation method on 15 July 2023. The plot was further divided into 4 sub-plots. In each treatment plot the plant-to-plant distance was 0.9 meter and row to row distance 2.4 meter. Each treatment plot contained 4 crop rows and 100 watermelons. They were spaced over 0.9 meters plots and blocks to prevent the passage of water from each other.

Good quality groundwater stored in a pool was used as irrigation water and was applied using the drip irrigation method. Fifteen polyethylene drip lines was installed at each row on 5000 square feet with 700 ammeters. On drip pipes the spaces between 2 ammeters were be 0.9 meter. Drip lines were connected PE manifolds placed along the edge of each plot. Total number of plants on each plot was 1500 grown on 1400 square meter. Agronomical practices such as weeding and field managements were also employed. Fertilizer as basal doze (Zerkhair + fertigation) was applied on each plot through urea broadcast. However, liquid fertilizers contain micro and macro nutrient was applied during growth period casually through fertigation tank to drip based fields.

Considered key parameters involved number of Irrigation, irrigation duration, total amount of irrigation, date of irrigation, starting and ending time of irrigation, irrigation Quantity, duration of diesel engine pump, fuel consumption (liter cost). The field originated experiment was taken into account the energy consumed through combustion processes of diesel in the numerous operations of Water melon (WM 777L.) cultivation like land groundwork, cultivation, seeding, picking, and transport of crops to cold storing facility and later to marketplace.

Harvesting, Measurements and Fruit Quality

Water melon (*Citrullus lanatus* L.) was harvested at the interval of 2-4 days during the initial ripening stage. The present study depends on Acre based estimation of Water melon (*Citrullus lanatus* L.) Crop production. At the experimental site the analysis of data was purely based on authentic farm practice and raw numeric data with particular applicable technique. During the harvesting period, Water melon (*Citrullus lanatus* L.) from twenty-four plants on the two rows in the middle of each plot were harvested by picking method. The selected growth parameters were root length (RL), Vine Length (VL), number of vines per plant, number of flowers per plant, leaf index (LI), Leaf Area (LA). Flowering dates were also recorded from the date of sowing.

3.1. Energy Footprint

Both mechanical and electrical energy consumed in the production of water melon (*Citrullus lanatus* L.**)** was calculated for DI and FI systems. Electrical energy refers to the amount of energy consumed for the purpose of irrigation purposes and for the watermelon production. Whereas mechanical energy refers to diesel consumed in land preparation, sowing and harvesting etc. It was calculated as a share of EF by applying diesel conversion factor to total/entire diesel consumption in MJ/L. The subsequent formula was used for the calculation of EF (Patel & Kumar 2013).

$$\text{Energy Footprint (EFK)} = \frac{\text{Total Electricity Consumed (KWh)}}{\text{Total Quantity Produced (Kg's)}}$$

3.2. Carbon footprint

According to accessible standards concerning CFP calculation the subsequent structured framework was tracked (BSI 2008; WRI/WBCSD 2004; Carbon Trust 2007).

3.2.1.Assortment of GHG's

Data related to GHGs is based upon the guideline and type of activity (Panday and Agrawal, 2014). CO_2 emission of agriculture was calculated by considered the water used under drip and flood irrigation methods followed by (Nelson & Robertson 2008; Shah 2009; Nezari et al. 2014).

3.2.2. Setting Boundaries

A boundary denotes to an imaginary line drawn around the activities utilized for the purpose of estimating carbon footprint. Illustrating boundary is essential to determine the activities that would mention in the study. In order to simplify appropriate accounting, the following tiers were considered (BSI 2008; Carbon trust 2007; WRI/WBCSD 2004).

(i) Tier 1 refers to direct emission for onsite emissions.
(ii) Tier 2 refers to indirect emission embodied in obtained energy.
(iii) Tier 3 covers all indirect emission such as those linked with waste disposal, business travel and sold goods etc.

Carbon footprint was divided into basic/primary carbon and full carbon. The primary carbon can be calculated under tier 1 whereas full carbon footprint covers emission up to tier 3 (Lynas 2007; Carbon Trust, 2007). In the present study the tier 1 was followed for calculating carbon footprint of watermelon grown under drip and flood irrigation methods.

3.2.3. Data assortment of GHGs emission

Estimation of GHGs emission and eliminations were connected with activities within the boundary that could be carried out either by direct measurement or assessed using emission models or factors (WRI/WBCSD, (2004)). In the present study the CO_2 emission was calculated by following the (Methodology of Nelson 2009; Shah 2009; Nezari et al. 2014).

Energy consumption by pump utilized for water abstraction for DI and FI system was calculated by using the elementary theoretical physical relationship defined as 0.0027 (KWh) of energy essential to lift water up to $1m^3$ (with density1000 Kgm^{-3}) through 1m at 100 percent efficiency. The subsequent relationship is revealed by the formula:

$$\text{Energy (kWh)} = \frac{9.8ms^{-1} \times \text{Lift (m)} \times \text{Mass (Kg)}}{3.6\times10^{6} \times \text{Efficiency \%}}$$

When the energy of pump is calculated, the CO_2 emission would be estimated by the subsequent formula as:

$$\text{GHG emission } (KgCO_2) = EC\ (KWh/m^3) \times \lambda_1\ KgCO_2/\ KWh$$

Where, EC is electricity amount/Quantity used consumed per unit water volume (KWh/m^3) and λ_1 is GHG emission conversion coefficient per (KWh) of electricity consumption/used which is equal to 1.69 $KgCO_2$ /KWh.

4. Statistical Analysis

The ANOVA was applied by using SPSS version 16.0 software to find out the significance of result between two irrigation systems in relation with total yield, yield components, water use efficiency and fruit quality. The significance was measured at 0.05 p-value.

5. Conclusion

It is concluded that a significant effect of irrigation system was observed on yield, EF and CFP. Drip irrigation system increased the yield of watermelon and decrease the release of carbon in the atmosphere with less consumption of water.

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Table 1 Agriculture activity and their classification into tiers

Activity	Cultivation practices	Source of energy	Tier
Land preparation	Plow	Diesel	$Tier_1$
Irrigation	Drip	Diesel	$Tier_1$
	Flood	Diesel	$Tier_1$
Fertilizer application	Fertigation	Diesel	$Tier_1$
	Urea Broadcast		

Table 2. Effect of DI and FI methods on crop yield and growth parameters of watermelon (*Citrullus lanatus* L.)

Irrigation systems	DI (Mean ± SE)	FI (Mean ± SE)
Number of veins per plant	7.35 ± 0.03	5.90 ± 0.02
Number of flowers per plant	8.00 ± 0.04	5.60 ± 0.02
Number of fruits per plant	5.20 ± 0.02	4.00 ± 0.06
RL(cm)	36.4 ± 0.03	26.4 ± 0.04
Fruit weight (kg)	5.40 ± 0.01	4.10 ± 0.04
Fruit size (D)	51.5 ± 0.01	41.9 ± 0.02
Vein length-VL (cm)	244.8 ± 0.03	190.3 ± 0.03
Leaf area-LA(cm)	9.41 ± 0.03	4.84 ± 0.02

Table 3. The energy requirement for irrigation, land preparation and transportation

Watermelon cultivation process	In DI system energy requirement (Kwh)	In FI system energy requirement (Kwh)
For irrigation	178	350
For mechanical land preparation and transportation	40	40
Total energy consumption	218	390

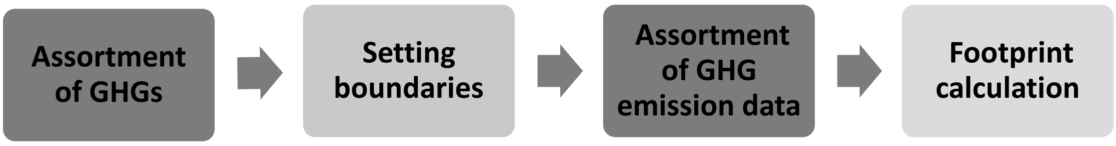

Figure 1 Structured framework for the estimation of CFP of watermelon (*Citrullus lanatus* L.)

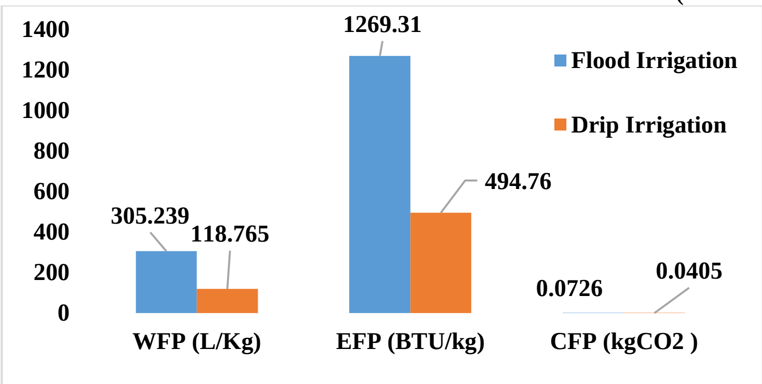

Figure 2. WFP, EFP and CFP of *Citrullus lanatus* L. grown under two irrigation systems.