Original Research Article   https://doi.org/10.20546/ijcmas.2017.605.277

Yield and Irrigation Water Use Efficiency of Bottle Gourd (*Lagenaria sicenaria* L.) In Response to Different Irrigation Methods and Planting Geometries

K.G. Rosin[1]*, R. Kaur[1], N. Patel[1], T.B.S. Rajput[1] and Sarvendra Kumar[2]

[1]Water Technology Centre, ICAR-Indian Agricultural Research Institute, New Delhi-12, India
[2]Division of Soil Science and Agricultural Chemistry, ICAR-Indian Agricultural Research Institute, New Delhi-12, India
*Corresponding author:

A B S T R A C T

A field experiment was conducted at the experimental area of Indian Agricultural Research Institute, New Delhi, during *kharif* season of 2011- 2013 to evaluate the effect of different crop geometries and irrigation methods on the yield and irrigation water use efficiency of bottle gourd (*Lagenaria Sicenaria L.*). The experiment consisted of three crop geometries (G_1 - row distance 3m and plant distance 0.5m, G_2 - row distance 2m and plant distance 0.75m and G_3 - row distance 1m and plant distance 1.5m) with two methods of irrigation (I_1- ridge & furrow and I_2 – check basin). Results revealed that, yield and irrigation water use efficiency were significantly affected by both the methods of irrigation and planting geometries. Ridge and furrow method of irrigation recorded significantly ($P<0.05$) higher yield (25 t ha^{-1}) as compared to check basin (21 t ha^{-1}) method of irrigation. Plant geometry G_1 recorded significantly higher yield (27.15 t ha^{-1}) as compared to G_2 (21.45 t ha^{-1}) and G_3 (19.45 t ha^{-1}). The yield attributes *viz.* fruit length and fruit girth was also found to be higher in the crop geometry G_1. The ridge and furrow method of irrigation resulted higher irrigation water use efficiency as compared to the check basin method. The study concluded that ridge and furrow method of irrigation with planting geometry of G_1 resulted highest mean yield (30.9 t ha^{-1}) and irrigation water use efficiency (467 kg ha^{-1}cm^{-1}).

Introduction

Water is the most vital input for agricultural production. Globally, of the total fresh water 69% is used in agriculture sector, 8% in domestic, 23% in industrial and other sectors. Though irrigation provides only 10% of agricultural water use and covers just around 20% of the cropland, it can vastly increase crop yields, improve food security and contribute about 40% of total food production since productivity of irrigated land is almost three times higher than that of rainfed land

(Singh *et al.,* 2010). In India, 82% of water is used in agriculture sector which covers around 80-million-hectare area under irrigation, but the share is going to be reduced because of developmental activities and liberalization of industrial policies. Because of this, ground water and surface water quality will also degrade with increased concentrations of salts and heavy metals (Rosin *et al.,* 2013). So, increased demand would be met from improving the water use

efficiency or productivity of currently available irrigation water. Improving water use efficiency by 40% on rainfed and irrigated lands would be required to counterbalance the need for additional withdrawals for irrigation over the coming years to meet the additional demand for food. Growing more crops per drop of water use is the key to mitigating the water crisis.

The efficiency improvements in surface irrigation methods are still a researchable issue as resource poor farmers in India are still practicing these methods for farming. Raised bed and ridge & furrow sowing methods have been found to give better crop establishment as well as yield by way of reducing the water loss and facilitating the drainage process. Bottle gourd (*Lagenaria siceraria)* is extensively grown in India with an area of 1.14 lakh ha with a total production of 20.9 lakh MT. It is rich in medicinal properties like cardio tonic, diuretic, antidote against certain poisons, controlling night blindness, cough, curing jaundice etc. and culinary preparations like cooked vegetables, sweets and pickles. Bottle gourd is all round fruit bearer with bottle shaped fruits and hard shells of mature fruits are used as water jugs, domestic utensils, floats for fishing nets, etc. Crop is grown during summer and rainy season. In places where water is not scarce, it is grown throughout the year. Due to improper crop and water management measures, the crop is not successful in kharif season. During kharif season the majority of rainfall is obtained in Indian subcontinent. The improper methods of irrigation may result water logging and subsequent yield loss in most vegetables. So, better land and water management strategies can increase the yield and water use efficiency of vegetable crops.

Generally, vegetables are crops with higher economic value and productivity per unit of applied water compared with field crops. In commercial vegetable productions, irrigation is crucial to achieve high economic returns, in terms of both yield and product quality. Because of that, farmers tend to over irrigate vegetable crops and, consequently reduced yield and irrigation efficiency (Stefania De Pascale *et al.,* 2011). Efficiency has been defined as the ability to produce the desired effect with the minimum effort, expenses, and waste (Jensen, 2007). Studies have shown that well designed and well managed surface irrigation systems have comparable application efficiencies to those of pressurized system. Therefore, it is important to improve surface irrigation systems and their management to increase application efficiency without lowering crop yield (Rana *et al.,* 2006). Keeping these facts, in this three-year experimental study we have attempted to identify the best surface irrigation method along with suitable planting geometries for bottle gourd cultivation. Effects on marketable yield and irrigation water use efficiency (IWUE) were measured for surface irrigated fresh market bottle gourds.

Materials and Methods

Experimental site

Field experiments were conducted at the Water Technology Center, ICAR- The Indian Agricultural Research institute, New Delhi, which is located at 28°8' N latitude and 77°12' E longitude. The mean annual rainfall based on 100 years' record (1901-2000) is 710 mm. About 80 per cent of the annual rainfall is received during monsoon (June-September) and some rainfall is also received during winter season (December-March). Humidity is high during the monsoon months. The soil, a sandy loam (SL), consists of 55% sand, 30% silt and 15% clay in upper 30cm of the soil profile. The bulk density ranges from 1.5 to 1.6g cm^{-3} in the soil profile. The

hydraulic conductivity of the soil profile is 1.6ml / hr. Available water holding capacity of soil is 82.5 mm/60 cm. Initial soil properties of the experimental site are given in Table 1. The irrigation water source was tube well and the results of quality analysis for the irrigation water applied having pH - 7.1, EC - 1.01(dS m^{-1}), Ca^{2+} 3.2 (me l^{-1}), Mg^{2+}-3.6 (me l^{-1}), HCO$_3$ - 3.6 (me l^{-1}) and RSC – 1, (me l^{-1}).

Irrigation methods and planting geometries

Surface irrigation methods *viz.* ridge & furrow and Basin methods were selected for the experiment, which was common among the farmers. Vegetable crops are high value crops with water utilization profile. Therefore, the areas with adequate water availability, farmers tend to over irrigate the crop which lead to wastage of the valuable natural resource and water logging problem. The recommended planting geometry for bottle gourd is 2m x 1 m. In our experiment, we tried to accommodate plants in such a way that the plant population (number of plants ha^{-1}) maintained the same with different planting geometries.

Treatments

The experimental design was applied using split plots in randomized blocks with four replications. The total six treatments were evaluated as two irrigation methods *i.e.* ridge & furrow and basin (main plots), and three different planting geometries (subplots) with same number of plant population per hectare (Table 2). However, the plant population per hectare was maintained constant in all the planting geometries i.e. 66.7 thousand. The length and width of experimental plots were 10 and 10m, respectively. Thus, the area of the plots was 100 m^2 and there are in total 24 plots with 2400 m^2 area. The experiment was

conducted for three consecutive years (2012-2014) in kharif season (July to October). The variety selected was Pusa Naveen which is extensively grown by farmers. 4-5 picking of the matured fruit were performed in the crop growth period and fruit length, girth was recorded as per standard protocol. Marketable yield was calculated on hectare basis.

Irrigation water use efficiency (IWUE)

Irrigation water use efficiency is defined as crop yield per water used to produce the yield. Thus, IWUE was calculated as fresh fruit weight (kg) obtained per unit volume of irrigation water applied (m^3).

Statistical analysis

For the statistical analysis, split-plots in randomized blocks with four replications were used to evaluate the effects of treatments on the yield. Analysis of variance was performed for each experimental year using SPSS. In addition, Duncan's multiple means test, regarded as an acceptable tool for the comparison of discrete data, was used to compare the different treatments (Yurtsever, 1984).

Results and Discussion

The effect of the treatments on marketable yield

The results of the marketable yield obtained according to the experimental years are given in Table 3. It is evident that the marketable yield varied widely from 18.9 to 34.4 t ha^{-1} depending on the treatments and experimental years. In addition, the data in Table 4 were derived from Table 3 to be seen separately affect the treatments in main and subplots on yield.

In 2011, the marketable yield varied from

20.0 to 34.4 t ha^{-1} depending on the treatments. Significant (*P < 0.05*) effect of different methods of irrigations and planting geometries on marketable yield was found together. That is, there was a significant interaction effect of the two factors. At the same time, the effects of the treatments in the main plots and subplots were also separately significant on yield (Table 4). The mean maximum yield was obtained with treatment I_1G_1 (30.74 t ha^{-1}) in which the method of irrigation was ridge and furrow and planting geometry was 3m (row to row spacing) x 0.5 m (plant to plant spacing). The treatment I_2G_2 produced a lowest yield of 22.6 t ha^{-1}; but it was in the same statistical group with the treatment I_2G_3 which produced a yield of 21 t ha^{-1}. The treatment $I_1 G_3$ in which the row to row spacing was 1m and plant to plant spacing was 1.5m produced a significantly smaller yield of 20.0 t ha^{-1} (Table 3). In 2012, the yields were obtained ranging from 18.9 to 29.4 t ha^{-1} (Table 3) depending on the treatments. There were significant effects ($P < 0.05$) in crop geometries were on observed in both the irrigation methods. These results were similar to the findings in 2011 in terms of effect of the treatments on the yield. Thus, the maximum yield of 29.4 t ha^{-1} was obtained from the treatment $I_1 G_1$. The treatment, in which the row to row spacing was 1m and plant to plant spacing was 1.5m, produced the lower yield compared to the planting geometries of row to row spacing of 2 m (row to row spacing) x 0.75 m (plant to plant spacing).

The yields obtained in 2013 varied from 20.1 to 28.6 t ha^{-1} (Table 3). Considering the statistical evaluation, there were significant effects of the different methods of irrigation on the amount of yield obtained ($P < 0.05$). In addition, different planting geometries, which were split plots of the experiment, had a statistically significant effect on the yield ($P < 0.01$) (Table 4). The treatments in split plots in 2013 had more significant effects on the

yields than the treatments in main plots, as in the experimental years of 2011 and 2012. The maximum yield of 28.6 t ha^{-1} was obtained in the treatment $I_1 G_1$ which was on par with the yield obtained in the treatments I_1G_2 and I_2G_1. The amounts of yield obtained in treatment $I_2 G_2$ were quite a lot lower than yields in treatment $I_2 G_3$ and I_1G_3 (Table 3).

The results of the study revealed that ridge and furrow method of irrigation has resulted average of 12 % higher yield as compared to basin method. Thakur *et al.,* (2011) also observed 16.7 % higher grain yield of sorghum in ridge and furrow against flat bed under Malwa Plateau condition of Madhya Pradesh. Considering the results in this study, it is argued that the water might be lost to evaporation and other losses in the basin irrigation method compared to ridge and furrow. Thus, plot yield decreased in basin irrigation. On the other hand, furrow irrigation resulted in a saving of 20 % of irrigation water without any significant reduction in the yield. These results were corroborated by the study conducted by Thind *et al.,* 2010, in which they compared the check-basin irrigation with each furrow and alternate furrow irrigation and showed irrigation water saving of 30 and 49% in bed-planted wheat and 20 and 42% in ridge-planted cotton respectively compared to basin. So, these results are, in general, in agreement with the results obtained in our study. In our study, the planting space of lesser plant spacing and wider row to row spacing (I_1G_1) resulted in an increase in yield per hectare due to trailing nature of the crop and better nutrient utilization.

Lesser plant spacing also help in retaining moisture of soil for longer period, which provided optimal condition for soil microbial communities that helped in nutrient transformation and ultimately improved nutrient supplying capacity of soil as also advocated by Kumar *et al.,* (2013).

Irrigation water use efficiency (IWUE)

Irrigation water use efficiencies ranged from 256 to 467 kg ha^{-1}cm^{-1} depending on the treatments and experimental years (Figure 1). Considering the averaged values, the maximum IWUE of 467 kg ha^{-1}cm^{-1} was obtained from the treatment I_1G_1 i.e. 3m (row to row spacing) x 0.5 m (plant to plant spacing) with ridge and furrow method of irrigation. Cetin and Ugyan (2008), showed the maximum irrigation water use efficiency (22.3 kg m^3) was obtained from 2-m lateral spacing in drip irrigation.

Table.1 Soil properties of the experimental site

Soil depth	pH	EC (dS/m)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	BD (g cm^3)	HC (ml hr^{-1})	Texture	Clay (%)	Sand (%)	Silt (%)
0-15	7.65	0.65	306.28	26.26	163.05	1.60	1.5	SL	15.68	55.16	29.16
15-30	7.56	0.62	294.54	25.5	160.25	1.6	1.6	SL	15.68	55.16	29.16

Table.2 The treatments applied for the experiment

Main plots (Irrigation methods)	Subplots (Planting geometries)
Ridge and Furrow (**I$_1$**)	3m (row to row spacing) x 0.5 m (plant to plant spacing)- **G$_1$**
Basin (**I$_2$**)	2 m (row to row spacing) x 0.75 m (plant to plant spacing) - **G$_2$**
	1 m (row to row spacing) x 1.5 m (plant to plant spacing) **G$_3$**

Table.3 The marketable yields and amounts of irrigation water applied according to the experimental years (2011-2013)

Treatment	Marketable yield (t ha^{-1})			
	2011 (1)	**2012 (2)**	**2013 (3)**	**Mean**
I$_1$ G$_1$	34.4[a]	29.4[a]	28.6[a]	30.9
I$_1$G$_2$	26.3[bc]	22.7[bc]	25.8[ab]	25.0
I$_1$G$_3$	20.0[d]	19.9[cd]	24.3[b]	21.4
I$_2$G$_1$	29.0[b]	25.1[b]	26.9[ab]	27.0
I$_2$ G$_2$	22.6[cd]	20.4[cd]	20.1[c]	21.1
I$_2$ G$_3$	21.0[d]	18.9[d]	23.6[b]	21.2

(1) Coefficient of variance (CV) = 9.3%, (2) CV = 12.8%, (3) CV = 8.4%. The same letters are not significantly different (*$P < 0.05$) according to a Duncan's multiple range test.

Table.4 The separated yields considering the treatments in the main and subplots

Irrigation methods (main plots)	Yields (t ha^{-1})				Plant geometry (subplots)	Yields (t ha^{-1})			
	2011	2012	2013	Mean		2011	2012	2013	Mean
I1	26.93	24.08	26.27	25.8	G1	31.7	27.3	27.8	28.9
I2	24.21	21.48	23.60	23.1	G2	24.5	21.6	23.0	23.0
					G3	20.5	19.5	24.0	21.3

Fig.1 Irrigation water use efficiencies (kg/ha-cm) according to the experimental years
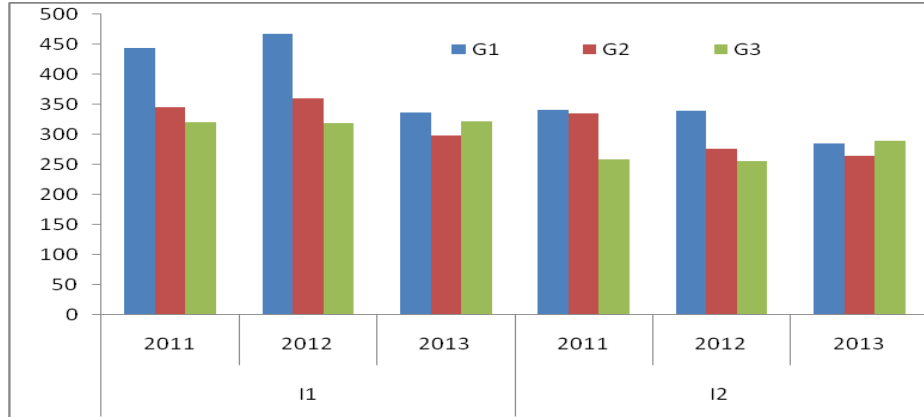
In the treatment I_1G_1, containing crop geometry 3m (row to row spacing) x 0.5 m (plant to plant spacing) and ridge and furrow irrigation method, IWUE was maximum *i.e.* 444 kg ha^{-1}cm^{-1} in the year of 2011. While in treatment I_2G_3 where crop geometry 1 m (row to row spacing) x 1.5 m (plant to plant spacing) and basin irrigation, IWEU was found the lowest *i.e.* 345 kg ha^{-1}cm^{-1}. Over the methods of irrigation, the maximum yield and IWEU was obtained in the crop geometry of 3m (row to row spacing) x 0.5 m (plant to plant spacing). On the other hand, minimum yield and IWEU was obtained in the crop geometry of 1 m (row to row spacing) x 1.5 m (plant to plant spacing). The reason may be rather than giving support for the growth of vines by putting poles; we adopted free trailing on the ground. So that row to row spacing had given enough space for trailing the vines on the ground. This practice helped the vines to uptake more plant nutrients effectively and grows without interrupting each other. In the consequent years also *i.e.* 2012 and 2013, the results showed same trend. The maximum IWUE was obtained in the treatment I_1G_1 *i.e.* 467 kg ha^{-1}cm^{-1} and 337 kg ha^{-1}cm^{-1} respectively in the year 2012 and 2013, while lowest IWUE was obtained in treatment I_2G_3 *i.e.* 256 kg ha^{-1}cm^{-1} and 289 kg ha^{-1}cm^{-1}. Thus, IWUEs differ considerable among the treatments and generally tends to increase with a decline in irrigation (Howell, 2006). The higher yield obtains also the higher IWUE. IWUE is a measure of the productivity of water used by the crops. IWUE is an important factor when considering irrigation systems and water management, and will become more vital in the water scare environment (Shdeed, 2001). On the other hand, water productivity can be increased by increasing yield per unit land area. In addition, water management strategies and practices should be considered in order to produce more crops with less water.

In conclusion, significant effect of different methods of irrigations and planting geometries on marketable yield was found together. Plant spacing affected significantly the yield per hectare. Even though the population density per hectare was same, still due to improved planting geometry over the farmer practice, we can increase the yield and IWUE. Highest yield (34.4 tons per hectare) and IWUE (467 kg/ha-cm) was recorded in 300cm row spacing and 50 cm plant spacing with ridge and furrow irrigation method. These results revealed that 300 cm row spacing and 50 cm plant spacing was the most beneficial spacing in terms of fruit weight, fruit girth, fruit length, number of fruits per vine and vine length. There are limited

techniques are available for increasing the efficiency of water use in irrigated agriculture. Reducing water application is typically minimized to achieve improved crop water use. As the results in this study, we have identified the best method of surface irrigation along with suitable planting geometry in bottle gourd which can maximize the yield and irrigation water use efficiency.

References

Cetin Oner and Uygan Demet. 2008. The effect of drip line spacing, irrigation regimes and planting geometries of tomato on yield, irrigation water use efficiency and net return. *Agri. Water Manage.,* 95: 949 –958.

Howell, T.A. 2006. Challenges in increasing water use efficiency in irrigated agriculture. *In: The Proceedings of International Symposium on Water and Land Management for Sustainable Irrigated Agriculture,* April 4–8, 2006, Adana, Turkey.

Jensen, M.E. 2007. Beyond irrigation efficiency. *Irr. Sci.,* 25: 233–245

Kumar, S., Patra, A.K., Singh, D., Purakayastha, T.J., Kumar M. and Rosin, K.G. 2013. Balanced fertilization along with farm yard manures enhances abundance of microbial groups in soil and their resistance and resilience against heat stress. Communication in Soil Science and Plant Analysis. 44, 2299–2313.

Rana M.A., Arshad M. and Masud J. 2006. Effect of basin, furrow and rain gun sprinkler irrigation systems on irrigation efficiencies, nitrate-nitrogen leaching and yield of sunflower. Pakistan Journal of Water Resources, 10(2): 1-7.

Rosin, K.G., Kaur, R., Singh, S.D., Singh, P. and Dubey, D.S. 2013 Groundwater Vulnerability to Contaminated Irrigation Waters—A Case of Peri-Urban Agricultural Lands around an Industrial District of Haryana, India. Procedia Environmental Sciences, 18, 200-210.

Shdeed, K. 2001. Economical and Technical Assessment of On farm Water Use Efficiency. United Nations, 01-106, New York, USA.

Singh Ravender, Kundu D.K. and Bandyopadhyay, K.K. 2010. Enhancing Agricultural Productivity through Enhanced Water Use Efficiency. *J. Agri. Physics,* 10: 1-15.

Stefania De Pascale, Luisa Dalla Costa, Simona Vallone, Giancarlo Barbieri and Albino Maggio. 2011. Increasing water use efficiency in vegetable crop production: from plant to irrigation systems efficiency, *Hort Technol.,* 21(3): 301-308

Thakur, N.S., Kushwaha, B.B. and Sinha, N.K. 2011. Productivity and water use in *kharif* sorghum under different land configuration and mulching. *Indian J. Agric. Sci.*, 56: 47-51

Thind, H.S., Buttar, G.S. and 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. *Irrig Sci.,* 28: 489–496.

Viets, Jr., F.G. 1962. Fertilizers and the efficient use of water. *Adv. Agron.*, 14: 223–264.

Yurtsever, N. 1984. Experimental statistical methods. Soil and fertilizer research institute, Ankara (Technical Pub. No.: 56, Pub. No: 121, in Turkish).