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Research Articles

Surge-flow alternate furrow irrigation for enhancing water productivity in semiarid regions

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ABSTRACT

The rainfed regions of India are characterized by aberrant behaviour of monsoon rainfall, eroded and degraded soils with multiple nutrient and water deficiencies, declining groundwater table and poor resource base of the farmers are major constraints for low and unstable yields. The successful production of rainfed crops largely depends on how efficiently soil moisture is conserved *in situ* or the surplus runoff is harvested, stored and recycled for supplemental irrigation and these are inevitable options to sustain rainfed agriculture in climate change scenario. For better use of harvested or recharged rainwater in *rabi* season, needs to evaluate and modify the present irrigation practices for enhancing the water productivity of rainfed regions. Keeping these considerations in view, an experiment was conducted during 2014–16 in farmer's fields of Panchmahal, Gujarat under Department of Science and Technology to study the effect of various furrow irrigation techniques on water saving, water productivity and yield of fennel (*Foeniculum vulgare* Mill.) crop. The treatments contained different furrow irrigation techniques such as furrow irrigation, plough furrow irrigation, alternate furrow irrigation with and without surge flow. The experimental data proved that the alternate furrow with surge flow irrigation is the best method that saves up to 78% of irrigation water without affecting the crop growth and yields. The surge flow, alternate furrow irrigation increased the water productivity and amount earned from unit of water over the check basin method of irrigation by 4 times. The saved irrigation water can bring the additional area under cultivation of high-value crops like fennel and vegetable during *rabi* season.

Key words: Alternate furrow, Fennel, Semi-arid region, Surge flow, Water productivity

India is a major seed spices producer in the world. In Western part of India, fennel (*Foeniculum vulgare* Mill.) mainly cultivating in Gujarat, Rajasthan and Madhya Pradesh. In Gujarat, it occupies an area of 38,000 ha with an annual production of 55000 metric tonnes (MT) in 2013–14 (National Horticulture Board). This crop is very profitable and good quality seeds are obtained from the semi-arid region of Gujarat. But agricultural production and productivity of semi-arid part of Gujarat are low due to rainfall dependence, lesser groundwater availability and absence of irrigation facilities. Farmers don't get sufficient water to irrigate their crops in entire area in post monsoon season. Only few farmers those are having wells are cultivating fennel crop in *rabi*. The farmers those are not having irrigation facilities are paying 1/3rd of their produce towards irrigation water. In such situations, right approach should be applied to irrigate the maximum area with reduced irrigation intensity in order to increase the overall production and water use efficiency in arid and semi-arid regions. Conventional irrigation has high degrees of water loss due to high evaporation rates and deep percolation losses, while sprinkler and surface drip irrigation involve the high cost of installation and depend heavily on labour.

Alternate furrow irrigation (AFI) is a modified form of deficit irrigation method whereby water is applied to every other furrow rather than to every furrow (Yao *et al.* 2012). Surge-flow furrow irrigation is an intermittent application of irrigation water to furrows, creating a series of on and off modes of constant or variable time spans. Advantages of applying surge and alternate furrow irrigation methods are to minimize deep percolation losses, runoff losses,water losses through evapotranspiration, plant redundancy growth and raise water use efficiency, uniform water distribution in entire field and higher crop yields (Kifle *et al.* 2008, Zhang

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et al. 2008, Liu *et al.* 2013). Keeping these considerations in view, an experiment was conducted to study the performance of different surface irrigation techniques with a combination of surge flow having several benefits such as; saving irrigation water, higher water distribution efficiency, and water productivity.

MATERIALS AND METHODS

Study area: The study was carried out at farmer's field in Navadh and Navagam Villages of Panchmahal district in the eastern part of Gujarat, India during 2014–16. Annual rainfall of this region is 753 mm, normal rainy days are 38. The 90% of the annual rainfall occurred in the monsoon, normal onset of monsoon rainfall is 3rd week of June, and normal cessation of monsoon rainfall is 1st week of October. The district is rainfed with a semi-arid climate and tribal dominant agrarian base. The major crops in the study area are maize, pigeon pea, fennel and cotton. The maximum temperature of this district is 45°C and the minimum temperature is 14°C and the soils are sandy loam.

Experimental details: To study the effect of various furrow irrigation techniques on water saving and yield of fennel crop treatments involved were different furrow irrigation techniques such as plough furrow irrigation, surge flow-plough furrow irrigation (Fig 1), alternate furrow irrigation, surge flow-alternate furrow irrigation, furrow irrigation, surge flow-furrow irrigation (Fig 2) and farmers practice (check basin). Irrigation was repeated at 10–12 days intervals, when the available soil water content was depleted to 20–30% in the soil profile. Fennel crop was planted during the first fortnight of November in 2014 and 2015.

Fig 1 Plough furrow irrigation.

Table 1 Water applied, savings, water productivity and economics of various furrow irrigation techniques (2014-16)

Treatment	Water applied (m^3/ha)	Water saving (%)	Water productivity (kg/m^3)	Economics ₹/m^3 of water
Plough furrow irrigation	4118	43	0.45	56.25
Surge flow-plough furrow irrigation	3033	58	0.65	81.25
Alternate furrow irrigation	2890	60	0.62	77.50
Surge flow alternate furrow irrigation	1632	78	1.17	146.25
furrow irrigation	5758	21	0.34	42.50
Surge flow furrow irrigation	4113	44	0.49	61.25
Check basin method (Control)	7280	-	0.27	33.75

Data collection and analysis: An amount of irrigation water applied for each irrigation and given treatment was collected by water meter installed in the pipeline. For each treatment, observations on plant growth and yield attributes and yield from each plot were collected and analysed. Plant height was measured from soil surface to the highest shoot tip by strengthening all branches. Stem width was measured from one centimetre above the base of the stem using Vernier calliper. Observations on number of branches, number of umbels, number of umbellate, number of seeds per umbellate were recorded by standard counting method.

RESULTS AND DISCUSSION

Water saving: The water applied during the crop period for each treatment was recorded and water saving, water productivity (kg/m^3) and water economics in (₹/m3) was worked out (Table 1). It is observed that highest water was applied by check basin method of irrigation. By this method farmers fill the complete basin sometimes up to 30 cm depth. Due to complete wetting of the ridges and furrows, any winds come, crop lodging was occurred and it occupy the space between crop rows and restricted free air circulation have

Fig 2 Plough furrow irrigation.

more chances for disease, pest attack, sometimes damage of umbles, umblets and thus reduces the yield. In normal furrow irrigation, water is applied continuously. When water applied by furrow and surge flow-furrow irrigation water was saved by 21% and 44% respectively. Under furrow irrigation water applied in surge, will double the water saving. Plough furrow irrigation treatment brought the water demand from 7280–4118 m^3/ha and saved the irrigation water by 43%. Adding plough furrow to surge irrigation is an additional advantage and saved irrigation water by 54%. In plough furrow irrigation only small part of furrow was wetted (Fig1) and thus enabled less irrigation water. Similarly, in case of alternate furrow irrigation only alternate furrows were irrigated and middle furrows were not irrigated (Fig 2) and thus enabled less water requirement. When water applied in surge flow alternate furrows reduced the irrigation water requirement from 7280–1632 m^3/ha (78%). Alternate furrow system has partial wetting and drying of root zone system periodically that results in better growth and yield and due to this reason yield reduction was not observed. The surge flow is better than the conventional flow in furrows interms of water applied and saving (Table 1). The surge flow method prevents water losses in irrigation as deep percolation losses, runoff etc. and provides uniform distribution of water in the crop root zone. Several studies such as Kifle *et al. (*2017), Horst *et al.* (2007), Kifle *et al. (*2008) and Ismail *et al.* (2004) were also confirmed that surge flow has less tail water and deep percolation losses than the continuous flow.

Water productivity and economics: The water productivity and economics for each treatment were worked (Table 1) and it can be seen that various furrow irrigation techniques have significantly increased the water productivity and amount earned from unit of water over the farmers practice (check basin method). The surge flow-plough furrow and alternate furrow irrigations double the water productivity and amount earned from unit of water over the check basin method of irrigation. The surge flow-alternate furrow irrigation increased the water productivity and amount earned from unit of water over the check basin method of irrigation by 4 times. The surge flow irrigation was significantly affected the irrigation performance indicators (application efficiency, distribution uniformity, deep percolation and tail water runoff losses), irrigation water use efficiency (Kafle *et al.* 2017). Alternate furrow irrigation increased the water use efficiency up to 35% (Tai-sheng *et al.* 2013). Kanber *et al.* 2012 reported that alternate furrow irrigation almost double (0.20–0.36 kg/m^3) water productivity over the conventional furrow irrigation. The alternate furrow with surge flow irrigation reduced the irrigation water losses in the furrows and maximise the yield and thereby higher water productivity and returns. It was also evidenced by Belder *et al.* (2005), Zhang *et al.* (2008), Han *et al.* (2013), Liang *et al.* (2013) and Liu *et al.* (2013) and Chu *et al.* (2014) that alternate furrow irrigation can maximize yield, save irrigation water, and reduce leaching of nutrients.

Growth parameters and yield: The growth parameters and yield of fennel crop for different furrow irrigation techniques are presented in Table 2 and it was observed that lesser growth and yield was recorded in plough furrow and alternate furrow irrigation plots. The yield reduction under plough furrow and alternate furrow irrigation plots over the check basin irrigation was 5 and 8% respectively. However, the growth and yield of surge flow plough furrow and alternate furrow irrigation plots are as per with the other irrigation treatments. It might be due to alternate furrow irrigation with surge flow provides the required amount of soil moisture to the plant root system. One side it is dry and another side it is wet, partial wetting and drying periodically provide better growth and yield and due to that reason yield reduction was not observed. It was also reported by Kifle *et al.* (2017) that alternate furrow and conventional furrow irrigation systems have insignificant effect on yield of onion. However, the irrigation flow methods continuous and surge flow systems significantly affected onion yield. When winds were blowing at the crop maturity stage, severe crop lodging was noticed in farmer's method (basin). Due to complete wetting of the ridges and furrows by check basin method, this crop lodging was occurred and it occupy the space between crop rows and restricted free air circulation so more chances for disease, pest attack, sometimes damage

Table 2 Growth parameters and yield of fennel crop under different furrow irrigation techniques (2014–16)

Treatment	Plant Height (cm)	Stem groirth (cm)	Branches/ Plant	No of mmbels/ plant	No of umbellate/ umbel	No of seeds/ umbellate	Yield (kg/ha)	% increase/ decrease over the control
Plough furrow irrigation	170	1.62	10.4	32.4	31	33	1863	-5
Surge flow-plough furrow irrigation	183	1.74	10.8	36.6	34	35	1933	-2
Alternate furrow irrigation	161	1.54	9.4	30.4	31	31	1816	-8
Surge flow alternate furrow irrigation	168	1.62	13.8	34.2	33	33	1924	-2
Furrow irrigation	170	1.64	14.2	42.6	32	36	1980	1
Surge flow furrow irrigation	178	1.7	16.7	44.7	37	38	2034	3
Check basin method (Control)	173	1.68	16	37.2	32	35	1969	

of umbels, umbellate and thus reduce the yield. This was due to excessive soil moisture in the root zone along with the blowing winds. Whereas in alternate furrow irrigation or plough furrow irrigation systems, the entire crop root zone was not wet and the dried part of the root zone will bind the roots and support the plants from lodging.

The productivity enhancement of rainfed regions largely depends on how efficiently rainwater conserved and managed and this inevitable option to sustain rainfed agriculture in climate change scenario. In the rainfed regions under limited water availability situation, easily adoptable and cost effective irrigation methods are the best option to increase the land and water productivity. Keeping these considerations in view, an experiment was conducted to study the performance of different surface irrigation techniques with combination of surge flow for fennel crop in *rabi* season. The surge flow-plough furrow irrigation saves 58% of irrigation water, double the water productivity and earnings from unit of water over the check basin method of irrigation. Alternate furrow with surge flow method of irrigation saves up to 78% of irrigation water without affecting the crop growth and yields. The surge flow-alternate furrow irrigation increased the water productivity and amount earned from unit of water over the check basin method of irrigation by 4 times. These methods prevents water losses in irrigation as deep percolation losses, runoff etc. and provides uniform distribution of water in the crop root zone. This method provides periodic partial wetting and drying of root zone system and prevents crop lodging. The saved irrigation water can bring the additional area under cultivation of high-value crops like fennel and vegetable during rabiseason.

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