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EFFECT OF DEFICIT IRRIGATION ON RAISED BED WHEAT CULTIVATION

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ABSTRACT. The experiment was conducted during Rabi season of 2015-2016 and 2016-2017 at the Regional Agricultural Research station, BARI, Ishurdi, Pabna, Bangladesh, to determine the water requirements of wheat on raised bed and the effect of different deficit irrigation on yield, water use efficiency and applied water productivity under raised bed wheat. This study consisted of following irrigation treatments: T_1 = Irrigations up to 100% field capacity (FC) at crown root initiation (CRI), botting and grain filling stages (flat bed), T_2 = Irrigations up to 100% FC at CRI, botting and grain filling stages on raised bed, T_3 = Irrigations up to 80% FC at CRI, botting and grain filling stages on raised bed and T_4 = Irrigations up to 60% FC at CRI, botting and grain filling stages on raised bed and laid out in a randomize complete block design with three replications.The result showed that significant effect of irrigation treatments were observed on plant height, spike per m^2 and grain yield. Highest grain yield (4.66 t/ha) was obtained from treatment, irrigations up to 100% FC at CRI, botting and grain filling stages on raised bed, followed by irrigation up to 100% FC at same stages on flat bed. At raised bed wheat cultivation saving 14.30% water with increasing 15.66% grain yield than flat bed. Besides, comparing deficit irrigation (20% and 40% of full irrigation) and full irrigation condition on raised bed seeding system water use could be reduced about 4.18% to 5.57%, while scarifying 18.20% to 32.33% grain yield, where reduced 14.17% to 27.54% water use efficiency. Maximum applied water productivity 1.81 kg m^{-3} was observed in raised bed full irrigation condition. The rate of daily evaporation started to increase as the temperature started to rise and humidity started to decrease during the crop growing period. The results will be helpful for taking policy decision regarding efficient irrigation and water management under prevailing water scarce situation.

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Keywords: inadequacy irrigation; water use efficiency; applied water productivity; bed planting.

INTRODUCTION

Water scarcity is a real threat to food production in arid and semiarid areas in Bangladesh. Crop productivity in semi-arid regions is mainly limited by water availability (Ehdaie *et al.,* 2011). Wheat, being the second cereal crop of Bangladesh, faces periods of water stress/drought due to shortage of water during the months of December to second decade of February. In Bangladesh, wheat is normally irrigated 3 to 4 times. First irrigation is given at 17-21 days after sowing at crown root initiation (CRI) stage. The subsequent irrigations are provided with an interval of 30 - 35 days. Water requirements of wheat vary from 180 to 420 mm (Balasubramaniyan & Palaniappan, 2001). Water shortage in the country demands to develop new technologies of seeding system where conserve soil moisture as well as irrigation method that can be helpful to utilize this precious input in an effective way. In addition there is also a need to carry out practices of irrigation water management to achieve high water use efficiency. To increase the area of irrigated land and hence to increase overall crop production using the same amount of available water, options that save water and improve yield (land productivity) and water productivity (WP) or crop water-use efficiency (grain yield/evapotranspiration) need to be developed. One of these potential options is deficit irrigation (DI), which is the application of a fraction of crop water requirements. Kirda (2002) reported that under scarce water-supply conditions, DI could lead to greater economic grain production than maximizing yields per unit of water applied for a given crop. Yield decrease is mainly due to the effect of water deficit on grain number per m^2 rather than grain weight (Farré & Faci, 2009). Kang *et al.* (2002) showed a 20 to 45% increase in grain yield of spring wheat by reducing irrigation by 30 to 60 mm during the jointing stage. Zhang *et al.* (2006) demonstrated that grain yield, harvest index and water-use efficiency were greatly improved under regulated DI, when compared to the non-stressed treatment. Metwally *et al.* (1984), Mohamed (1994), El-Bably (1998) and El- Sabbagh *et al.* (2002) showed that wheat plants irrigated to around 50 to 60% of soil moisture depletion gave significantly increased grain yields. A review of measured crop water productivity (Zwart & Bastiaanssen, 2004) concluded that this practice increased WP in many crops including maize and wheat. Galavi & Moghaddam (2012) showed that yield, harvest index, water use efficiency and evapotranspiration efficiency were affected by deficit irrigation.

Raised bed planting is another technique that allows water saving. The bed planter is a new piece of technology introduced by USAID's

CSISA-MI project in Bangladesh. Raised bed wheat cultivation is a modern technology in Bangladesh of conservation agriculture. Raised beds are a farming system where seeds were sown directly and distinctly separated the crop and traffic zones (furrows). The flat top of the bed is constructed by moving soil from the traffic lane to the crop zone. The furrows act as traffic zones or tramlines to which wheels are confined and also as conduits for irrigation water supply and drainage. Bed planting has shown improved water distribution and efficiency, fertilizer use efficiency, reduced weed infestation, crop lodging and reduced seed rate without sacrificing yield (Hobbs *et al.,* 2000). Sayre & Hobbs (2004), using wheat data from different countries, showed increases in grain yield and water productivity. It also provides an opportunity for hand weeding an economical option because of the easy field entry resulting from crop row orientation on the beds, and irrigation water management is more efficient, with less labor required with the use of furrows than with conventional flood irrigation. Fischer *et al.* (2005). Wheat flat planting with flood irrigation leads to inferior water use efficiency and lower crop yield. This practice also results in greater crop lodging and enhanced frequency of crop diseases Fahong *et al.* (2004).

The present research was done with the aim to determine the water requirements of wheat on raised bed and the effect of different deficit irrigation on yield, water use efficiency and applied water productivity under raised bed wheat.

MATERIALS AND METHODS

The experiment was conducted at Regional Agricultural Research station, BARI, Ishurdi, Pabna, during Rabi season of 2015-2016 and 2016-2017. The experimental site was a silty clay loam having field capacity of 28.5%, permanent wilting point at 13% and bulk density of 1.49 g cm^{-3}. Four irrigation treatments were assigned in a Randomize Complete Block Design with three replications. Seed of BARI Gom -28 was sown in unit plots of size was 7 × 7.5 m, on raised bed in 40 cm base width, 20 cm top width, 15 cm height and maintained 20 cm distance between two beds by using the bed planter and was subjected to following irrigation treatments: T_1 = Irrigations up to 100% FC at CRI, botting and grain filling stage (flat bed), T_2 = Irrigations up to 100% FC at CRI, botting and grain filling stage on raised bed, T_3 = Irrigations up to 80% FC at CRI, botting and grain filling stage on raised bed and T_4 = Irrigations up to 60% FC at CRI, botting and grain filling stage on raised bed. Seeds were sown on 24 November 2015 and 20 November 2016, harvested on 13 March 2016 and 10 March 2017, respectively. Common irrigation was applied up to field capacity, 80% and 60% of field capacity to ensure germination. SMD was determined by estimating soil moisture content. For this purpose, soil samples were taken from the effective root-zone of the wheat plant, which is 0-45 cm. The root-zone was divided into three sections, *viz.* 0-15, 15-30 and 30-45 cm. Soil samples were collected from these three sections with the help of an auger. The fresh weight of the soil sampled was recorded immediately with the help of a portable weighing balance. After weighed, the samples were stored in soil sampling core, which were then placed in an electric oven for 24 h at 100°C. The dry weight of the samples was recorded after oven dry. Soil moisture contents were then calculated as under:

$$\text{Soil content moisture (\%)} = \frac{\text{Fresh weight of the sample}}{\text{Dry weight of the sample}} \times 100$$

The following irrigations were applied according to the specified treatments and irrigation water was applied up to field capacity at full irrigation treatment and deficit irrigation treatments up to 80% and 60% of field capacity of each irrigation. The amount of water applied to each treatment was calculated on the basis of the soil moisture contents at the time of irrigation by using the following expression:

$$d = M.C. \times B.D. \times D,$$

where, d = depth of water to be applied (mm); M.C. = moisture content (%); B.D. = bulk density of the soil (g/cc); D = depth of root-zone to be irrigated (mm).

The depth of rooting was considered 45 cm. It is reported that 70% of total moisture is extracted from the 50% effective root zone depth (Michael, 1985). The seasonal crop water use was calculated by the following relationship:

$$SWU = NIR + Rf + \sum_{i=1}^{n} \frac{(Mbi - Mei)}{100} \times A_{Si} \times D_i \ ,$$

where, SWU = seasonal water use (mm); NIR = total irrigation water depth (mm); Rf = seasonal rainfall (mm); Mbi = moisture percentage at the beginning of the season in the each layer of the soil; Mei = moisture percentage at the end of the season in the each layer of the soil; n = no. of soil layers in the root zone (3);

(This was considered of three of layers, 0-15, 15 –30, and 30 – 45 cm); Di = Depth of the each layer of soil within the root zone (mm); Asi= apparent specific gravity of each layer of soil.

Water use efficiency and productivity of total applied water was used in evaluating the yield performance and water management practices. The productivity of total applied water (PAW) is defined as crop yield per unit volume of water supply to the crops, following Molden (1997), and is estimated by dividing crop yield, by total applied water (rainfall + irrigation). Effective rainfall will be calculated using Farmwest calculator (http:// www. farmwest. com/ node/934):

Effective precipitation (mm) = (RAIN - 5) x 0.75

All other agronomic practices were carried out uniformly. The grain yield was recorded after harvest. Data on yield and yield components were analyzed statistically, using R-stat platform. In addition, meteorological data on parameters like temperature, relative humidity, rainfall and daily pan evaporation was also recoded.

RESULTS AND DISCUSSION

Climatic parameter

Decade wise daily temperature and relative humidity are graphically presented in *Fig. 1*, during the wheat growing period. Temperature and humidity showed a direct influence on the rate of daily evaporation. Positive correlation coefficient was found between temperature and E_{pan} (*Fig. 2*) and it is clearly indicated that the temperature increased with the rate of evaporation increased; however, a negative correlation between relative humidity and rate of pan evaporation (*Fig. 2*) indicated an inverse relationship. Thus, rate of evaporation was low, when temperature was low and humidity was high and the rate of evaporation started to increase as the temperature started to rise and humidity started to decrease. These agree to Balasubramaniyan & Palaniappan (2001), who stated that high temperature increases the rate of evapotranspiration, while relative humidity (RH) has its effect on transpiration. So, it is clear that climatic factors like temperature, relative humidity, affect the rate of consumptive use. Stomata of most species tend to close when RH is low and open when it is high. The rate of transpiration is relatively low and increases as the moisture in the air decreases. They further stated that movement of air removes accumulated water vapor near leaf surfaces and increase the transpiration. However, high wind velocities often induce stomata closure due to rapid water loss from the guard cells causing a decrease in transpiration. Total rainfall (45 mm) will be occurred during grain filling stage at 2015-2016 seasons and there is no rainfall occurred in 2016-2017 season. Effective rainfall was calculated to be 30 mm, using Farmwest calculator, during growing period.

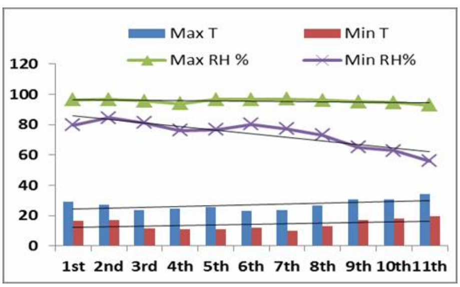

Figure 1 - Climatic parameters at growing period (Decade wise)

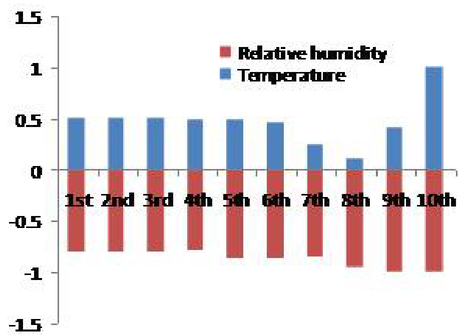

Figure 2 - Simple correlation coefficients of maximum temperature and relative humidity with pan evaporation (Epan) during the growing season (Decade wise)

Soil moisture depletion

The patterns of soil moisture content at different irrigation level showed in *Figs. 3a,b,c*, during growing period. The variations of temperature can be related to patterns of soil moisture depletion**.** The rate of moisture depletion was low during earlier growth period when temperature was low. As the temperature rise up in the later part of the growth period, the rate of soil moisture depletion also increased.

In *Fig. 3c* showed soil moisture depletion between two tillage systems, where trend of soil moisture depletion was higher in flat bed conventional system than bed planting seeding system, that indicated bed planting seeding system conserve more soil moisture. This is in line with Ohiri *et al.* (1990), who observed higher soil moisture content under conservation tillage (minimum tillage) than conventional system. Mohamed *et al.* (2012) also revealed that conservation tillage techniques improved soil moisture stored within the root zone, as compared to the conventional harrowing using the wide level disc.

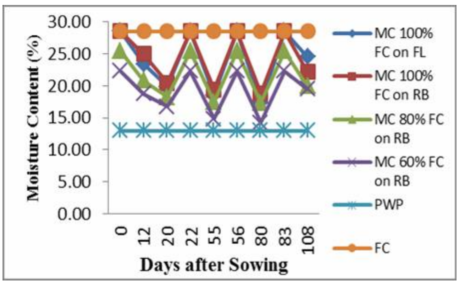

Figure 3a - Patterns of soil moisture depletion at different irrigation level during growing period (2015-2016)

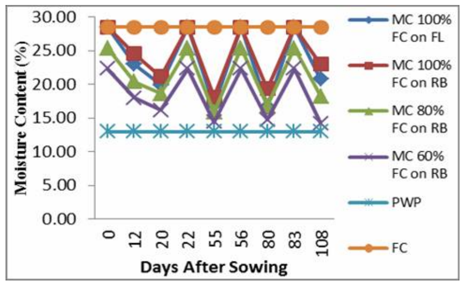

Figure 3b - Patterns of soil moisture depletion at different irrigation level during growing period (2016-2017)

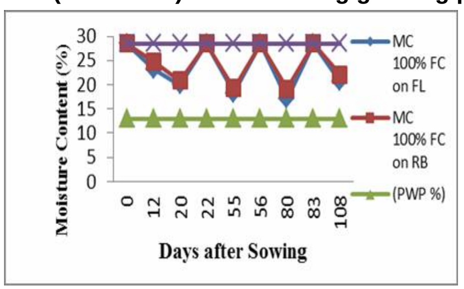

Figure 3c - Patterns of average soil moisture depletion at irrigation up to 100% FC on raised bed and flat land

Irrigation water and seasonal water use

Irrigation water and seasonal water use was graphically presented in *Figs. 4a* and *b*. Highest irrigation water and seasonal water were used to wheat, at irrigations up to 100% FC on flat bed and lowest were used to irrigation at 60% FC on raised bed. Irrigation water saved in 14.30% and seasonal water saved in 12.30% at raised bed than flat bed. However, water applied decreased by increasing deficit irrigation. These results agree with Aggarwal & Goswami (2003), who showed that total water use by the crop was reduced nearly by 5 cm, under treatment with three rows of wheat per bed, compared to conventional planting. Hossain *et al.* (2004) observed all permanent bed tillage systems also showed substantial water saving (32%) over the conventionally tilled on the flat bed. Mollah *et al.* (2009) also indicated that bed planting of wheat saved 41-48% irrigation water over flat land. Parihar *et al.* (2017) observed 100 mm more water consumption in conventional tillage plots than the permanent bed plots. These advantages come from the bed planting system that irrigation water advances faster between two beds, less percolation loss due to untilled furrow and compacted furrow bottom, as well as furrow side causes two wheeler passing at sowing time, less percolation loss occurred in raised bed soil than flat bed soil due to raised bed soil less tilled than conventional tillage on flat bed.

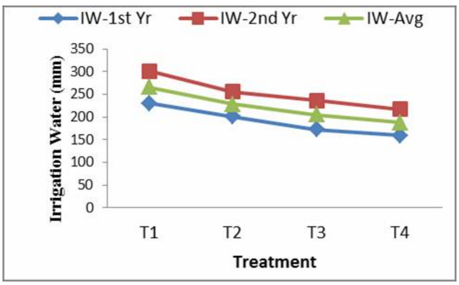

Figure 4a - Irrigation water variation in different treatments

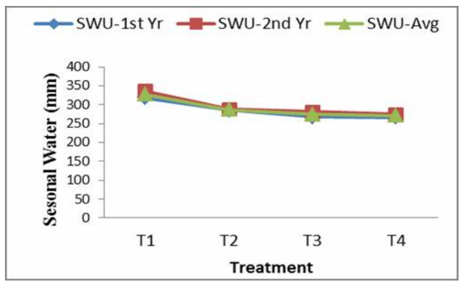

Figure 4b - Seasonal water variation in different treatments

Soil moisture contribution

Plant received highest soil moisture from deficit irrigation treatment and lowest from full irrigation treatment showed in *Fig. 5*. Highest soil moisture contribution was observed to 53 mm in 60% deficit irrigation treatment and lowest was 29 mm in full irrigation on raised bed. Soil moisture contribution rises with increasing deficit irrigation. At deficit irrigation conditions, where scarcity available water, plant try to forcedly uptake water from soil and received more soil moisture up to reached permanent wilting point.

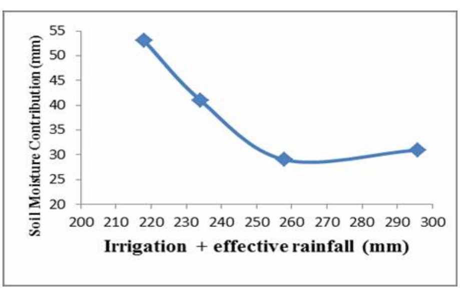

Figure 5 - Correlation between soil moisture contribution with crop water supply

Water use efficiency

Water use efficiency for fully and deficit irrigation treatments were showed in *Fig. 6.* Thus, the maximum water use efficiency (1.67 kg·m^{-3}) was found in irrigations up to 100% FC at CRI, botting and grain filling stage on raised bed, while the minimum (1.21 kg·m^{-3}) was observed in flat bed full irrigation condition. At deficit irrigation condition on raised bed, irrigations up to 60 % FC at CRI, botting and grain filling stages gave lowest value 1.21 kg·m^{-3}. Aggarwal *et al.* (2003) showed that water use efficiency increased by 0.03 t/ha/cm, under treatment with three rows of wheat per bed, compared to conventional planting. Ram *et al.* (2013) also observed soybean and wheat planted on raised bed recorded about 17% and 23% higher WUE, respectively, than in flat layout. The water use efficiency (WUE) was maximum under the treatment where crop was sown on bed with 68 cm bed width having six rows, as compared to conventional flat sowing (Waraich *et al.,* 2010).

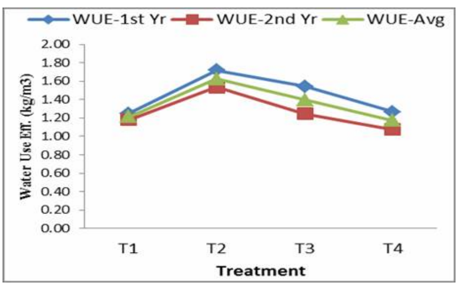

Figure 6 - Variation of water use efficiency among the treatments

Relation of crop production, productivity of applied water (PAW) and water use efficiency (WUE) to the crop water supply

Relation of yield, PAW and WUE to the crop water supply are presented in *Fig. 7.* Maximum productivity of water applied (1.81 kgm^{-3}) was found in irrigation up to 100% FC at CRI, botting and grain filling stage on raised bed treatment, while the minimum (1.33 kgm^{-3}) was observed in flat bed full irrigation condition. At deficit irrigation condition on raised bed, irrigations up to 60 % FC at CRI, botting and grain filling stages gave lowest value of 1.45 kgm^{-3} and highest value of 1.63 kgm^{-3}.

Yield, water use efficiency, applied water productivity were founded highest where used 258 mm of water. Water use efficiency and applied water productivity both are higher in deficit irrigation on raised bed, compared to full irrigation on flat land conventional tillage. However, highest yield, water use efficiency, applied water productivity were found full irrigation on raised bed.

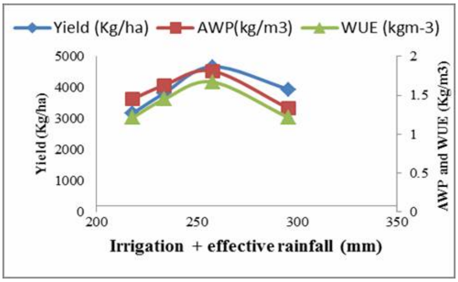

Figure 7- Relation of crop production, productivity of applied water (PAW) and water use efficiency (WUE) to the crop water supply

Grain yield and yield contributions characters

Significant effect was found on plant height, spike per m^2 and grain yield among the irrigation treatments. Mollah *et al.* (2009) mentioned that bed planting increased the number of panicles m^{-2}, number of grains $panicle^{-1}$ and 1000 grain weight of wheat (*Table 1*). Highest grain yield (4.66 t/ha) was obtained from treatment, irrigations up to 100% FC at CRI, botting and grain filling stages on raised bed over irrigation up to 100% FC at same stages on flat bed. Similarly, Aggarwala *et al.* (2003) showed that yield and water use efficiency increased by 0.22 t/ha, under treatment with three rows of wheat per bed, compared to conventional planting. Hossain *et al.* (2004) and Mollaha *et al.* (2009) also found that planting of wheat on bed increased grain yield up to 21% over flat planting. Majeed *et al.* (2015) showed that wheat planting on bed and nitrogen application at 120 kg ha^{-1} produced 15.06% higher grain yield than flat planting at the same nitrogen rate. Hameed & Solangi (1993) suggested that wheat planted on bed and furrow irrigation showed higher yield and water use efficiency than flat-planted wheat. Grain yield increased in bed planting, compared to flat planting mostly, because of deposition of more fertile topsoil on bed and because weeds were also concentrated mainly in furrows owing to the lack of crop cover there and the higher moisture content under the changed land configuration. Bed planting also reduced the soil surface exposed to flooding, eliminating surface soil crusting on top of the bed where wheat was planted. In bed planting, the microclimate within the field was also changed by orientation of the wheat plants in rows on top of the beds, and created favorable soil conditions for mineralization of native, as well as applied nutrients.

Besides, at deficit irrigation system highest grain yield (3.82 t/ha) was founded in irrigated at up to 80% field capacity, which closely, followed by treatment full irrigation condition on flat bed and up to 60% field capacity treatment gave lowest yield (3.16 t/ha), that was statically significant to irrigated at up to 80% field capacity on raised bed, full irrigation condition on raised and flat bed, respectively. Finally, these result showed a loss of grain yield by increasing deficit irrigation level from low to high on raised bed. These results agree with Alia *et al.* (2007), who observed the highest grain yield was obtained with the no-deficit treatment. Mugabea & Nyakatawab (2000) also observed applying three quarters and half of the wheat water requirements resulted in a yield decrease of 12 and 20%. The water deficit reduces grain yield when applied at any physiological growth stage, but the extent of damage varies from stage to stage (Malik & Ahmad, 1993). El-Sabbagh *et al.* (1997) found that applying irrigation when soil water content was at 80% of field capacity gave the highest yield, as compared to applying water at 65 and 50% of field capacity. However, Farré & Faci (2006) found that in maize and sorghum WP decreased with decreasing irrigation. Tari (2016) observed that the water deficits applied in the stem elongation and heading stages significantly decreased the wheat yields.

Table 1 - The effect of irrigation on grain yield and yield contributions characters (pooled average of 2015-2016 and 2016-2017)

Treatments	Plant height (cm)	Spike length (cm)	Spike/m^2 (no.)	Grain/spike (no.)	1000 grain weight (g)	Yield (t ha^{-1})
T_1	98.88	14.00	273.67	46.83	46.92	3.94
T_2	99.43	14.44	312.55	48.74	47.97	4.67
T_3	96.60	13.88	236.03	47.43	44.33	3.82
T_4	95.33	13.77	200.23	46.99	45.78	3.16
LSD(0.05)	1.61	ns	13.69	ns	ns	8.43
CV (%)	2.77	1.09	62.00	2.26	4.00	0.58

ns = non significant

CONCLUSION

From the study, supports the following observations, on comparing the results of raised bed wheat cultivation to conventional farming techniques at full irrigation condition; it was found that saving 12.30% seasonal water and 14.30% irrigation water with increasing 15.66% grain yield and 38% water use efficiency. Besides, comparing deficit irrigation (20% and 40% of full irrigation) and full irrigation condition on raised bed seeding system water use could be reduced about 4.18% to 5.57%, while scarifying 18.20% to 32.33% grain yield where reduced 14.17% to 27.54% water use efficiency.

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