



Actual Evapotranspiration, Water Expense Efficiency and Grain Yield of Chickpea under Varying Irrigation Regimes

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ABSTRACT

Background: Chickpea crop is water sensitive amongst the pulse crop. It can grow leftover moisture with lifesaving water supply through irrigation during grain filling stage. Timely irrigation is important at crucial growth stages to achieving higher chickpea yield. In present study, the actual seasonal evapotranspiration, water expense efficiency and grain yield of Chickpea varieties under varying irrigation have been evaluated.

Methods: The field trial was laid out at the AB block farm of BCKV, Kalyani with a split-plot design with two chickpea varieties (i) V₁- Bidisha and (ii) V₂- Purva, in the main plots and three irrigation frequencies (i) I₁-irrigate once only at 30 days after sowing (DAS); (ii) I₂- irrigate twice on 30 and 50 DAS and (iii) I₃- irrigate thrice on 30, 50 and 70 DAS replicated thrice during the *rabi* season of 2020-21 and 2021-22.

Result: The water expense efficiency was highest (1.32 kg m⁻³) under I₁ irrigation frequency by Bidisha variety followed by Purva variety recorded highest WUE 0.95 kg m⁻³. The maximum chickpea yield (2040 kg ha⁻¹) was harvested from Bidisha and was 23.04% greater than Purva mean over two years in I₃ irrigation regime. Considering the output of the study cultivation of Bidisha with three irrigations can be suggested to the farmers of the region.

Key words: Actual evapotranspiration, Chickpea varieties, Grain yield, Water expense efficiency.

INTRODUCTION

Chickpea is an important winter legume crop in India and popularly known as Bengal gram, or Brown gram (Patel *et al.*, 2022). Chickpea has multiple uses as *i.e.* leafy vegetable, roasted green pod, chana dal, germinated seeds and flour (Manjunatha *et al.*, 2024). Several dishes *i.e.* snacks, sweets and dishes can be made from flour. Chickpea grain contains about 25.5% proteins (Pooja and Sarawad, 2019) and 60.5% carbohydrates (Biabani and Sajadi, 2018). The brown chickpea occupies around 80% and the white gram around 20% productions in the world. India is the leading country contributing about 70% of the world's total production (Naz Farha *et al.*, 2018; Muehlbauer and Sarker, 2017). The area of chickpea crop rises from 7.57 million hectares in 1950-51 to 9.93 million hectares in 2013-14 productivity rise up from 4.80 q/ha to 9.65 q/ha (Loria *et al.*, 2022; FAOSTAT, 2018). Chickpea production differed year to year because of adverse weather during winter season and recorded a sharp decline over years. Chickpea is a suitable winter pulse crop for farmers to grow on residual soil moisture, *i.e.* with limited irrigation facilities; one to two irrigations is very much essential for terminal heat stress in drier tract (Yucel, 2018; Raghavendra *et al.*, 2017). The irrigation at right time in appropriate critical stages improves crop water productivity (Kelimo, 2022). Less amount of soil water contribution crop is faced certain level of water stress during crop growth (Asaf *et al.*, 2023, Chetariya *et al.*, 2024). The less supply of irrigation increases water productivity (WP) and decreases cost of cultivation (Osuna-Amador *et al.*, 2023). The cultivation of chickpea in rice fallow has many approaches for higher grain production. In low to medium

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land soil dominated by clay loam soil is suitable for chickpea. The leftover moisture with lifesaving irrigation is congenial for chickpea yield (Hedayetullah and Sadhukhan, 2018).

Chickpea crop is water sensitive among the pulse crop. It can grow on residual soil moisture during germination, establishment and early growth but in later stage lifesaving water supply through irrigation is needed. Bengal gram is can grow wide adaptability of land *i.e.* marginal lands and less scope of supplementary irrigation. However, there are reports on crop improvement related to optimum irrigation (Kumar *et al.*, 2021) water use pattern of prominent chickpea crops is major concern. Number of leaf per plant and leaf area decrease due to water stress that means evapotranspiration is major concern (Tiwari *et al.*, 2024). The water losses from the soil and from plant

are referred to as evapotranspiration (ET) as experiment is actual evapotranspiration concern in pulse crops. Water use efficiency (WUE) can enhance with proper irrigation scheduling (Amiri *et al.*, 2021).

The scenario of water use pattern winter pulse crops need to reshape for *kharif* followed by *rabi* season. There is possibility to take second crops under this region after rice with application of two irrigation optimum grain yield may be harvested (Hedayetullah *et al.*, 2018). In water scares areas, crop varieties and irrigation schedule helps to achieve higher yield and water use efficiency (Kamboj *et al.*, 2024). The aim of this trial was to evaluate the effect of actual evapotranspiration, water expense efficiency and grain yield of chickpea varieties under varying irrigation.

MATERIALS AND METHODS

Location and soil type

The trial was conducted in *rabi* season of 2020-21 and 2021-22 at AB block farm of BCKV, Kalyani (22°59'15.5"N 88°25'30.1"E). Soil parameters of trial plot were low organic carbon with clay loam texture having pH of 6.8, Electrical conductivity of 1.26 ds m⁻¹ and BD of 1.28 g cm⁻³. The soil of experimental field was silty clay (Table 1). Important soil physiochemical properties are presented in Fig 1.

Experimental design

The field trial was set out with a split-plot design with two chickpea varieties (i) V₁- Bidisha and (ii) V₂- Purva, in the main plots and three irrigation frequencies (i) I₁-irrigate once only at 30 days after sowing (DAS); (ii) I₂- irrigate twice on 30 and 50 DAS and (iii) I₃- irrigate thrice on 30, 50 and 70 DAS. Depth of irrigation was 50 mm and replicated four times. The data were analysed statistically for comparing the treatments means. The rainfall and pan evaporation loss are presented in Fig 1.

Agronomic practices

Land was prepared by drawn disc harrow with 20 cm tillage depth and finally given indigenous leveler. Bidisha and

Purva were sown on month of November and mature crop harvested at the age of 120-130 days. Plant geometry was 0.3×0.1 m. and fertilized with 20:40:40 as N, P₂O₅ and K₂O kg ha⁻¹.

Soil water storage

The soil water content (θ_m) was measured gravimetrically at 0.0-0.15, 0.15-0.3, 0.3-0.45, 0.45-0.6 0.6-0.75 and 0.75-0.90 m depths on sowing and harvest. Soil was oven dried at 100°C for two days. The soil water content was taken on depth basis (q_d) and the unit was in mm. Depth basis soil water content of the entire root zone profile (0-900 mm) *i.e.* θ_{dt} was obtained by adding the depth basis soil water content of each layer as:

$$\theta_{dt} = \sum \theta d_{0-150} + \theta d_{150-300} + \theta d_{300-450} + \theta d_{450-600} + \theta d_{600-750} + \theta d_{750-900}$$

At harvest stage mature chickpea crop has cut in 9.6 meter square area and then it converted to Mg ha⁻¹ as a grain yield.

Water expense efficiency (WEE)

It is computed using the following standard formulae:

$$WEE \text{ (kg m}^{-3}\text{)} = \frac{GY \text{ (Mg ha}^{-1}\text{)}}{WE \text{ (mm)}}$$

WEE = Water expense efficiency

GY= Grain yield

WE= Water expense.

Table 1: Important chemical properties of the experimental soil.

Properties	Status
pH	6.8
Electrical conductivity	1.26 ds m ⁻¹
Organic carbon (%)	0.65 %
Available nitrogen	232 kg ha ⁻¹
Available phosphorus	68 kg ha ⁻¹
Available potassium	189 kg ha ⁻¹
Olsen extractable arsenic	2.62 mg kg ⁻¹

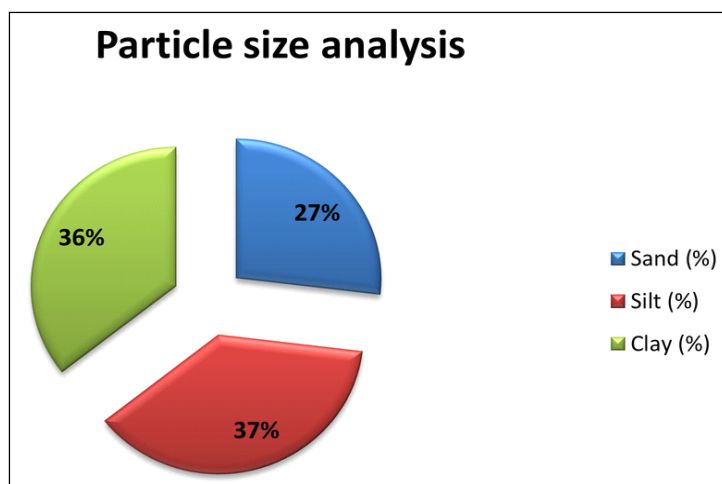


Fig 1: Particle size of the experimental soil.

RESULTS AND DISCUSSION

Water balance component

Precipitation

The cropping season of experiment was in dry winter, rainfall occasionally occurred. During the cropping season rainfall occurred in 2021-22 and less rain was occurred in 2020-21. The total precipitation during study period in 2021-22 was 223 mm which is depicted in rainfall bar along with evaporation (Fig 2).

Irrigation regimes

Irrigation was given with different frequencies on two chickpea varieties. In V_1I_1 treatment, plot was irrigated once only at 30 days after sowing (DAS) and total irrigation was given 50 mm during cropping season and in V_1I_2 treatment, plot was irrigated twice on 30 and 50 DAS and total irrigation was given 100 mm during cropping season. In this way, in V_1I_3 treatment, plot was irrigated thrice on 30, 50 and 70 DAS. Total irrigation was given 150 mm during the cropping season (Table 2). Depth of irrigation was 50 mm in each plot and in each replication. The irrigation frequencies (Alla *et al.*, 2015) at vegetative and reproductive stages with 7-10 days interval showed effective to achieve higher chickpea yield.

Soil water storage study

During the cropping season the highest soil water storage (82.33 mm) was obtained under treatment V_1I_1 in Bidisha crops in 2021-22. The soil water content was decreasing towards I_2 and I_3 respectively. The lowest soil water storage (25.41 mm) was obtained under treatment V_2I_3 in Purva crops in 2020-21 (Table 2). In case of Bidisha crops soil water content decreased by 30% and 36%, respectively under I_2 and I_3 irrigations frequencies in 2020-21 whereas in Purva crops soil water storage decreased by 15% and 58%, respectively under I_2 and I_3 irrigations frequencies in 2020-21.

Actual evapotranspiration

Among these two chickpea varieties Bidisha crop plot having maximum actual evapotranspiration compare to the Purva variety. The maximum actual evapotranspiration (396.12 mm) was obtained under treatment V_1I_3 in Bidisha crops in 2021-22. It has been found that the AET increased notably with an increase in frequency of irrigation regimes and significant amount of rainfall. Actual evapotranspiration (AET) from Bidisha field increased by 19.42% and 38.35%, respectively under I_2 and I_3 irrigations frequencies in 2020-21 and AET from Purva field increased 26.60% and 36.64%, respectively under I_2 and I_3 irrigations frequencies in 2020-21.

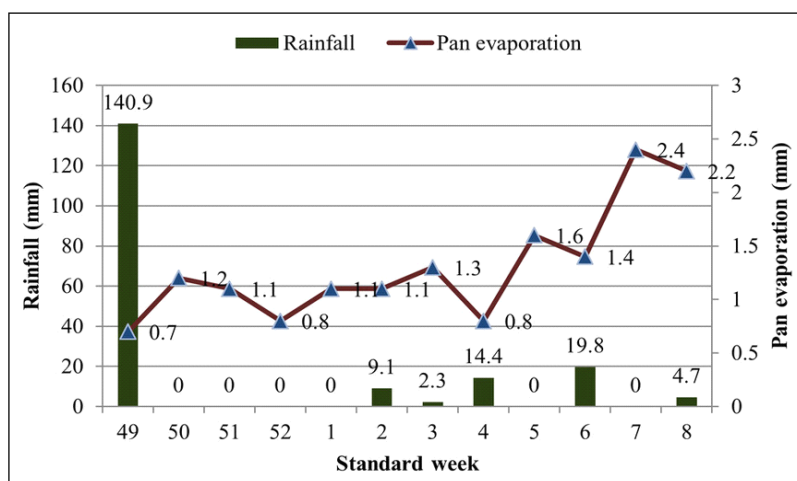


Fig 2: Rainfall (bar) and pan evaporation (line) status during 2021-22.

Table 2: Components of water balance for two varieties under varying irrigation regimes.

Treatments	Rainfall		Irrigation		Δ SWS		AET	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
V_1I_1	0.00	191.20	50.00	50.00	69.94	82.33	119.94	323.53
V_1I_2	0.00	191.20	100.00	100.00	48.85	66.53	148.85	357.73
V_1I_3	0.00	191.20	150.00	150.00	44.56	54.92	194.56	396.12
V_2I_1	0.00	191.20	50.00	50.00	61.13	73.51	111.13	314.71
V_2I_2	0.00	191.20	100.00	100.00	51.42	65.15	151.42	356.35
V_2I_3	0.00	191.20	150.00	150.00	25.41	40.18	175.41	381.38

V_1 = Bidisha, V_2 = Purva, I_1 = Irrigation at 30 days after sowing (DAS), I_2 = Irrigation at 30 and 50 DAS, I_3 = Irrigation at 30, 50 and 70 DAS.

The similar trend of AET was recorded in 2021-22 in both varieties under different irrigation regimes depicted in Table 2.

Grain yield and actual evapotranspiration relationship

There is effective linear correlation between yield and actual evapotranspiration. The relationship between grain yield and actual evapotranspiration is presented in Fig 3 and 4. Obtained yield varied from 1.53 to 1.93 Mg ha⁻¹ and 1.03 to 1.54 Mg ha⁻¹ in bidisha and purva variety respectively in 2020-21 and similar trend also observed in the year of 2021-22 (Table 3). The yield of chickpea water use pattern was confirmed by Ray *et al.*, 2011. The seasonal actual evapotranspiration was recorded 119.94 to 194.56 mm and 111.13 to 175.41 mm in Bidisha and Purva crops respectively in 2020-21 and the similar curve was obtained

in successive year of study 2021-22 (Table 2) and (2020-21). Fig 3 and 4 showed a relationship between grain yield (y) and actual ET (x), marked with high R² value as given below:

$$Y = 0.001 SET^2 - 36.49; R^2 = 0.465$$

$$i. y = -6.672x^2 + 87.209x + 37.087; \text{----(year-2020-21)} \\ R^2 = 0.4549$$

$$ii. y = -6.672x^2 + 53.683x + 292.44; \text{----(year-2021-22)} \\ R^2 = 0.5467$$

Results showed that about 45.49% and 54.67% in 2020-21 and 2021-22 respectively grain yield variation could be results for SET. The Y- SET relationship supported the findings of Ali (2017) and Oweis *et al.* (2004).

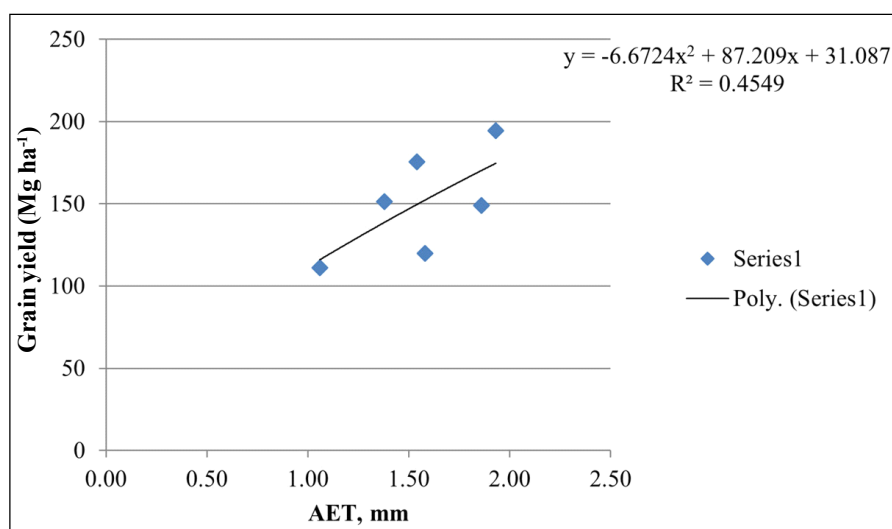


Fig 3: Grain yield and actual evapotranspiration relationship under varying irrigation frequencies in 2020-21.

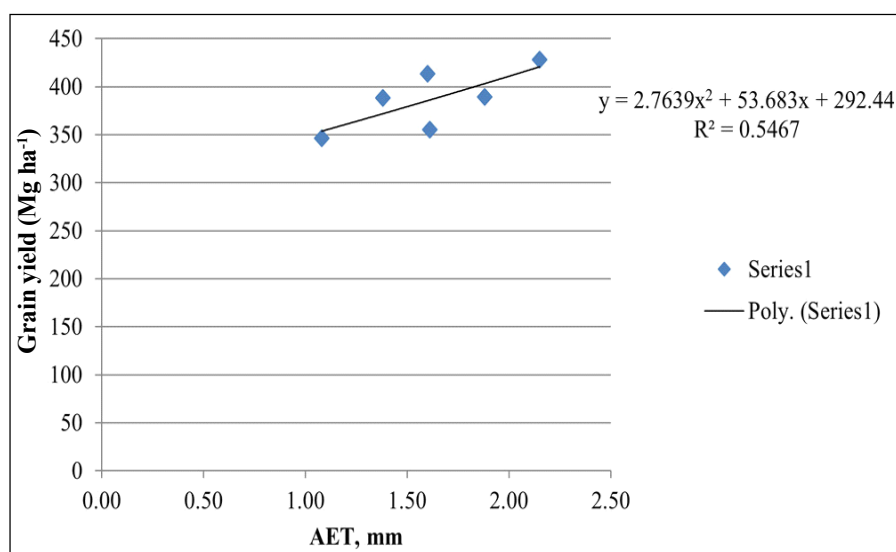


Fig 4: Grain yield and actual evapotranspiration relationship under varying irrigation frequencies in 2021-22.

Water expense efficiency

The highest WEE (1.32 kg m^{-3}) under I_1 treatment in 2020-21 (Table 3) by Bidisha variety. In Purva variety recorded highest WUE 0.95 kg m^{-3} in I_1 treatment in 2020-21. The decreased at 5.14% and 24.67%, respectively under I_2 and I_3 irrigations levels in 2020-21 for Bidisha variety. In case of Purva variety decreased by 4.2% and 7.4%, respectively under I_2 and I_3 irrigations frequencies in 2020-21. In both the varieties having decreasing trend obtained in water use efficiency. Whereas in 2021-22, both the varieties having increasing trend obtained in water use efficiency may be due to the second year rainfall contribution. Ali (2017) and Oweis *et al.* (2004) showed the higher water use efficiency found in less irrigated treatments.

Seasonal actual evapotranspiration and water expense efficiency relationship

The relationship between Seasonal actual evapotranspiration (SET) and water use efficiency (WEE) is presented in Fig 5 and 6. Measured water expense efficiency (WEE)

varied from 1.32 to 0.99 kg m^{-3} and 0.95 to 0.88 kg m^{-3} in Bidisha and Purva varieties respectively in 2020-21. Ali (2017) and Sarkar *et al.* (2016) reported that water expense efficiency in mulch plot it indicates less

Table 3: Impact of irrigation regimes on grain yield and water use efficiency (WEE) for two chickpea varieties.

Treatments	Yield, Mg ha^{-1}		WEE, kg m^{-3}	
	2020-21	2021-22	2020-21	2021-22
$V_1 I_1$	1.58	1.61	1.32	0.50
$V_1 I_2$	1.86	1.88	1.25	0.53
$V_1 I_3$	1.93	2.15	0.99	0.54
$V_2 I_1$	1.06	1.08	0.95	0.33
$V_2 I_2$	1.38	1.38	0.91	0.38
$V_2 I_3$	1.54	1.60	0.83	0.43
CD ($p = 0.05$)	0.92	0.96	1.11	0.74

V_1 = Bidisha, V_2 = Purva, I_1 = Irrigation at 30 days after sowing (DAS), I_2 = Irrigation at 30 and 50 DAS, I_3 = Irrigation at 30, 50 and 70 DAS.

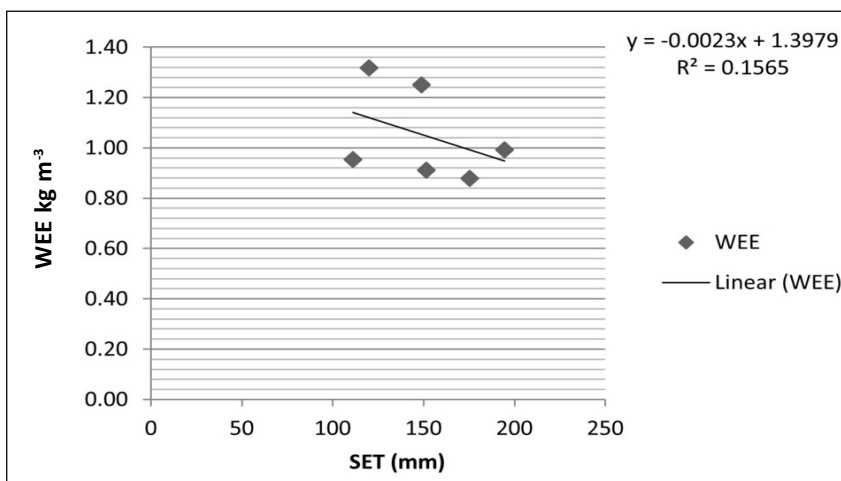


Fig 5: Seasonal actual evapotranspiration and water use efficiency relationship under varying irrigation frequencies in 2020-21.

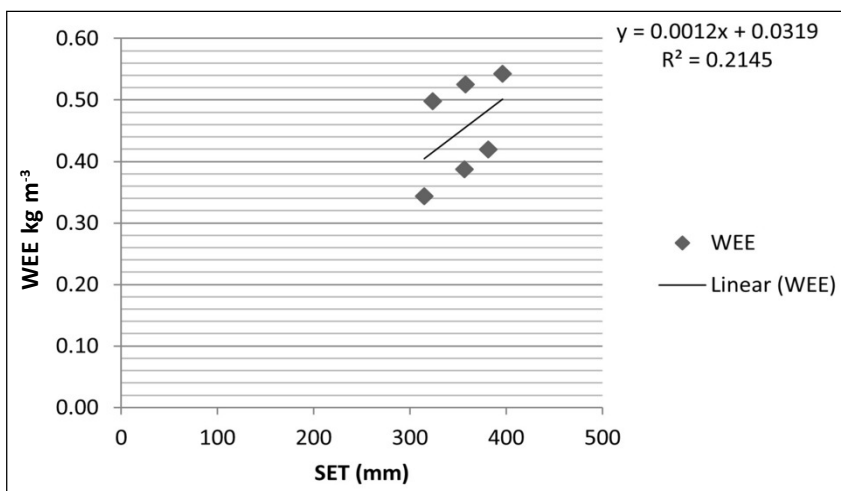


Fig 6: Seasonal actual evapotranspiration and water use efficiency relationship under varying irrigation frequencies in 2021-22.

number of irrigation applied. The similar curve was obtained in successive year of study (2021-22). Fig 5 and 6 showed a linear relationship between seasonal actual evapotranspiration (SET) and water use efficiency (WEE), marked with high R^2 value as expressed below:

$$\text{i. } y = -0.0023x + 1.3979 \text{-----}(\text{year-2020-21}) \\ R^2 = 0.1565$$

$$\text{ii. } y = -0.0012x + 0.0319 \text{-----}(\text{year-2021-22}) \\ R^2 = 0.2145$$

Results showed that about 15.45% and 21.45% in 2020-21 and 2021-22 respectively of the variations in water expense efficiency (WEE) could be attributed due to variation in Seasonal actual evapotranspiration. The relationship confirmed by Razzak *et al.* (2017 and Fernandez-Garcia *et al.* (2013).

CONCLUSION

Value of actual evapotranspiration (AET) loss from Bidisha field was marginally higher over Purva variety during the cropping season. In total maximum grain yield was harvested from Bidisha field which was greater than Purva. Highest amount (150 mm) of irrigation water application resulted in lowest value of water use efficiency. In study area chickpea grown in winter season, in this region water scarcity is very common. Considering the output of the study cultivation of Bidisha with two irrigations can be suggested to the farmers of the region. There is possibility to take second crops under this region after rice with application of three irrigations to achieve optimum grain yield.

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Conflict of interest

The authors declare no conflict of interest.

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