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Response of wheat genotypes to different irrigation schedules based on IW/CPE ratios

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Abstract

The IW/CPE ratio defined as the depth of Irrigation Water (IW) applied when Cumulative Pan Evaporation (CPE) reaches a set threshold is a simple, weather-driven tool for scheduling irrigation in cereal crops. This research examined the response of six bread wheat genotypes to four IW/CPE ratios (0.6, 0.8, 1.0, and 1.2) at the field research station of the University of the Philippines Los Baños during the 2022-2023 dry season. Grain yield increased from 3.04 t ha⁻¹ at IW/CPE 0.6 to 4.03 t ha⁻¹ at IW/CPE 1.0, but showed no further gain at 1.2 (3.98 t ha⁻¹). Water use efficiency (WUE), however, declined steadily from 1.42 kg m⁻³ at 0.6 to 0.91 kg m⁻³ at 1.2. Genotype HD-3086 outyielded all others across irrigation levels, producing 4.12 t ha⁻¹ at IW/CPE 1.0 with a WUE of 1.13 kg m⁻³. The interaction between genotype and irrigation was significant for grain yield ($p < 0.01$), indicating that some genotypes respond more to additional water than others. An IW/CPE ratio of 0.8-1.0 appears to offer the best balance between yield and water productivity for wheat in the Los Baños environment.

Keywords: Wheat, irrigation scheduling, IW/CPE ratio, water use efficiency, genotype response, pan evaporation, deficit irrigation, grain yield, evapotranspiration, tropical dry season

Introduction

The IW/CPE approach schedules irrigation by dividing a fixed irrigation depth by cumulative pan evaporation, so that water is applied whenever the ratio reaches a predetermined value ^[1]. A lower ratio (e.g., 0.6) creates mild deficit by waiting longer between irrigations, while a higher ratio (e.g., 1.2) supplies water more frequently, often exceeding crop demand ^[2]. The method requires only an evaporation pan and a rain gauge tools available to most experiment stations and many farmer cooperatives making it far cheaper than soil-moisture sensors or weather-model-based scheduling ^[3].

Wheat (*Triticum aestivum* L.) is not a traditional crop in the Philippines, but interest has grown in the upland areas of Laguna and Batangas provinces where a cool, dry season from November to March provides a suitable window ^[4]. Yields remain below 3 t ha⁻¹ on most farms, partly because irrigation timing is guesswork rather than science. Over-irrigation wastes water and promotes lodging; under-irrigation during the grain-filling stage can cut yields by 20-35% ^[5, 6]. Genotypic differences in water-use strategy add another layer. Some wheat lines maintain stomatal conductance and photosynthesis under mild water deficit (anisohydric behaviour), while others close stomata early to conserve water but sacrifice carbon gain (isohydric behaviour) ^[7]. Matching genotype to irrigation regime could therefore amplify water productivity gains beyond what either factor achieves alone ^[8, 9]. This research tested six wheat genotypes at four IW/CPE ratios to identify the combination that maximises yield and WUE for the Los Baños dry-season environment ^[10].

Soil and water characteristics

The trial was laid out on an upland field at the UPLB Experimental Farm (14.17° N, 121.24° E, elevation 28 m). The soil is a clay loam Typic Tropudalf with 34% clay, 38% silt, and 28% sand. Topsoil (0-30 cm) had pH 5.8, organic carbon 1.24%, total N 0.11%, Olsen P 14.7 mg kg⁻¹, and exchangeable K 0.38 cmol kg⁻¹. Field capacity was 32.6% and permanent wilting point 16.8% by volume. Irrigation water from an artesian well had EC 0.34 dS m⁻¹ and pH 6.9, well within acceptable limits for wheat ^[11].

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Seasonal weather conditions

The crop season ran from 22 November 2022 to 19 March 2023. Mean daily temperature was 25.4 °C, with minimum of 20.1 °C (January) and maximum of 33.7 °C (March). Total rainfall during the growing period was 64 mm, concentrated in a single event in late January. Cumulative Class-A pan evaporation for the season was 487 mm. Mean relative humidity ranged from 72% in December to 63% in March. Weather data were recorded at the UPLB Agrometeorological Station located 300 m from the trial site.

Material and Methods

Material

Six bread wheat genotypes were evaluated: HD-3086, PBW-550, WH-1105, DBW-88, Kundan, and UP-2338. Seed was sourced from the UPLB Plant Breeding Division. Plots were sown on 22 November 2022 at 100 kg seed ha⁻¹ in rows spaced 20 cm apart. Basal fertiliser comprised 120 kg N, 60 kg P₂O₅, and 40 kg K₂O ha⁻¹, with half the N applied at sowing and the remainder top-dressed at crown root initiation [5]. A USWB Class-A evaporation pan was installed adjacent to the experimental area; daily readings were taken at 08:00 h.

Methods

Four IW/CPE ratios were tested: 0.6, 0.8, 1.0, and 1.2. Each

Results

irrigation applied a fixed depth of 50 mm through border strips when CPE accumulated to 83.3, 62.5, 50.0, and 41.7 mm, respectively. The experiment was a split-plot design with irrigation as the main plot and genotype as the subplot, replicated three times. Main plots measured 20 m × 6 m; subplots 3.3 m × 6 m. Soil moisture was monitored at 0-30 and 30-60 cm with a capacitance probe at weekly intervals. At harvest, a 3 m² area per subplot was cut; grain yield (adjusted to 12% moisture), 1000-grain weight, spikes m⁻², and grains per spike were recorded. Seasonal Evapotranspiration (ET) was estimated by the water-balance method. WUE was calculated as grain yield divided by ET [12]. Data were analysed by split-plot ANOVA in R 4.3.1; means separated by Tukey's HSD at $p=0.05$.

Field experimental design

The split-plot layout assigned four IW/CPE ratios to main plots and six genotypes to subplots within three blocks. Blocks were aligned along the field slope (< 0.5%) to manage surface drainage. Buffer strips of 1.5 m separated main plots to prevent lateral water movement between irrigation treatments. Irrigation volumes were metered with inline flow meters to confirm that the target 50 mm depth was delivered within ± 5% [3].

Table 1: Grain yield (t ha⁻¹) and yield components of six wheat genotypes averaged across four IW/CPE ratios

Genotype	Yield (t ha ⁻¹)	Spikes m ⁻²	Grains spike ⁻¹	1000-GW (g)
HD-3086	3.84	347	41.8	39.2
PBW-550	3.41	321	38.4	36.7
WH-1105	3.62	334	40.1	37.8
DBW-88	3.57	329	39.6	38.1
Kundan	3.23	308	36.9	35.4
UP-2338	3.36	316	37.7	36.1
LSD (0.05)	0.21	14.3	2.1	1.6

HD-3086 produced the highest mean grain yield (3.84 t ha⁻¹) across irrigation levels, followed by WH-1105 (3.62 t ha⁻¹) and DBW-88 (3.57 t ha⁻¹). Kundan ranked last at 3.23 t ha⁻¹. Spike

density and grains per spike showed parallel rankings, with HD-3086 producing 347 spikes m⁻² and 41.8 grains per spike both significantly above Kundan's values.

Table 2: Effect of IW/CPE ratio on grain yield, evapotranspiration, and water use efficiency (mean of six genotypes)

IW/CPE Ratio	No. of Irrigations	ET (mm)	Yield (t ha ⁻¹)	WUE (kg m ⁻³)
0.6	4	228	3.04	1.42
0.8	5	304	3.62	1.28
1.0	7	381	4.03	1.09
1.2	9	452	3.98	0.91
LSD (0.05)		23	0.18	0.09

Grain yield rose significantly from IW/CPE 0.6 to 1.0 but plateaued at 1.2, where the additional two irrigations didn't translate into extra yield. WUE moved in the opposite direction,

declining from 1.42 to 0.91 kg m⁻³ as more water was applied. The IW/CPE 0.8 treatment achieved 89.8% of the maximum yield while using 20% less water than the 1.0 treatment.

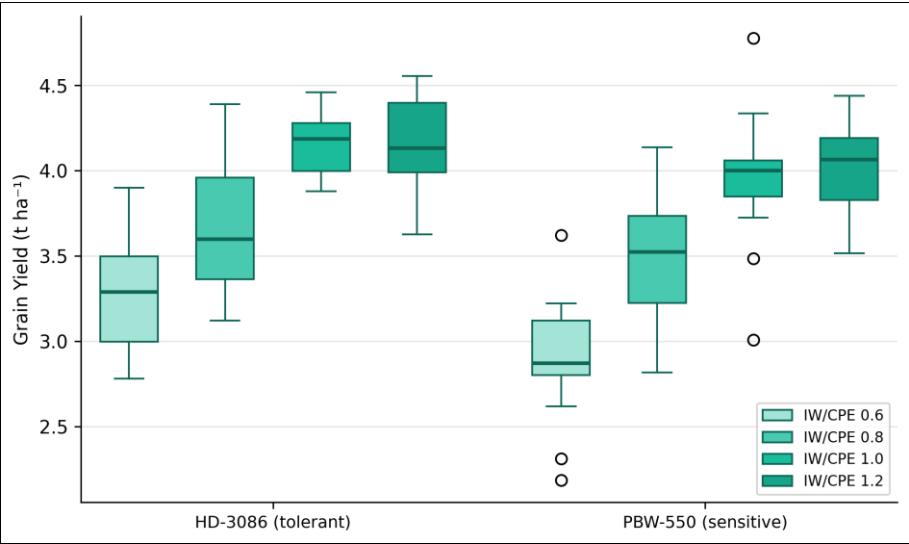


Fig 1: Box plot of grain yield for two contrasting wheat genotypes (HD-3086 and PBW-550) across four IW/CPE ratios

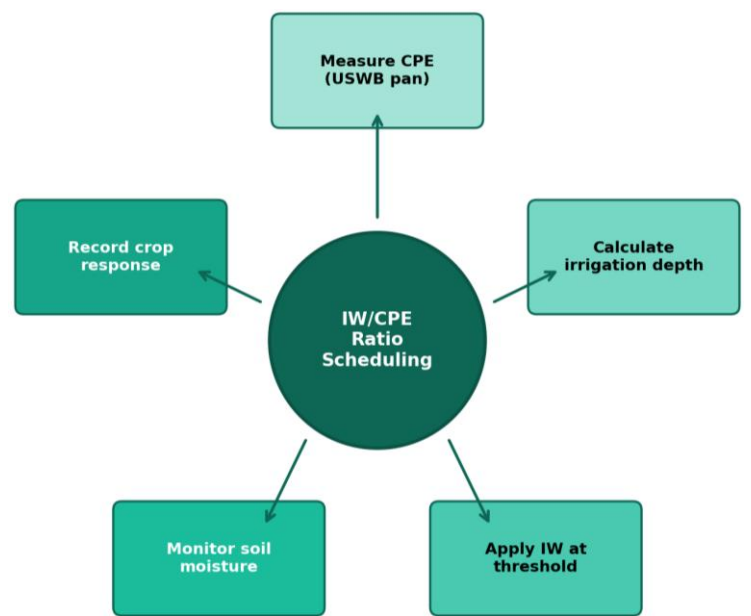


Fig 2: Cycle diagram illustrating the IW/CPE irrigation scheduling process, from pan evaporation measurement to crop response monitoring

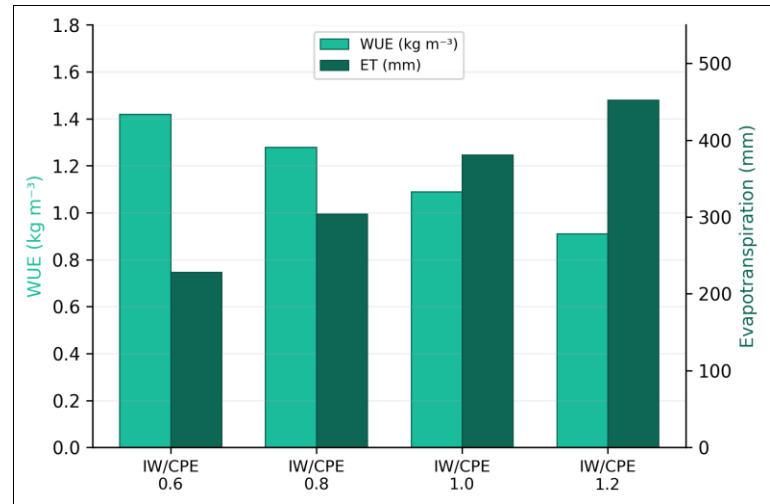


Fig 3: Water use efficiency and seasonal evapotranspiration of wheat under four IW/CPE irrigation ratios

Comprehensive interpretation

The genotype × irrigation interaction was significant ($p<0.01$) for grain yield. HD-3086 gained 28.3% yield moving from

IW/CPE 0.6 to 1.0, while Kundan gained only 18.7% over the same range. This suggests HD-3086 has a stronger capacity to convert additional water into grain a trait linked to sustained

stomatal opening and higher radiation use efficiency under well-watered conditions. The yield plateau at IW/CPE 1.2 indicates that the soil's drainage capacity was exceeded, likely causing transient waterlogging that offset any benefit of extra water supply.

Discussion

The yield plateau at IW/CPE 1.0 matches findings from subtropical wheat trials in India and Pakistan, where ratios above 1.0 often failed to improve grain yield and sometimes reduced it through excess vegetative growth or lodging^[2, 5]. On the clay loam soil at UPLB, the ninth irrigation under the 1.2 treatment fell in the grain-filling stage when soil was already near field capacity, likely promoting temporary root-zone saturation that hampered oxygen supply to roots^[6].

WUE declined linearly with increasing IW/CPE, a pattern consistent with the diminishing marginal return of each additional unit of water^[12]. The 0.8 ratio stands out as a practical compromise: it captured 89.8% of maximum yield while saving 77 mm of water per season compared with IW/CPE 1.0. For the UPLB environment, where dry-season water allocation is limited and shared among several crops, this saving translates to enough water for an extra 0.15 ha of irrigated area^[3].

HD-3086's consistent superiority across irrigation levels is likely tied to its longer grain-filling period (38 days versus 31 days in Kundan), which allows it to accumulate more assimilate without needing additional water^[7, 8]. Its higher spike density and grains per spike indicate better tillering capacity and fertile floret retention. For the emerging wheat-growing areas around Los Baños, pairing HD-3086 with an IW/CPE ratio of 0.8-1.0 could raise farm-level yields from the current 2.5-2.8 t ha⁻¹ range to well above 3.5 t ha⁻¹^[13].

Conclusion

Among the four IW/CPE ratios tested, 1.0 produced the highest grain yield (4.03 t ha⁻¹) but 0.8 achieved 89.8% of that yield with 20% less water, making it the most water-efficient schedule. The 1.2 ratio offered no yield advantage and reduced WUE to 0.91 kg m⁻³, confirming that surplus irrigation beyond crop demand wastes water on this clay loam soil.

HD-3086 was the top-performing genotype across all irrigation levels, yielding 3.84 t ha⁻¹ on average and reaching 4.12 t ha⁻¹ at IW/CPE 1.0. Its strong performance under both deficit and adequate moisture conditions makes it a versatile choice for the variable water-supply situations that characterise dry-season farming in Laguna province.

For practical recommendations, farmers with reliable water access should target IW/CPE 1.0 with HD-3086, while those facing water constraints would do well with IW/CPE 0.8 paired with the same genotype. Multi-year trials across different soil types in the UPLB region are warranted to confirm these single-season results before scaling to extension recommendations.

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