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Effect of fog duration and intensity on growth and yield of potato in the Terai region

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Abstract

Winter fog in the Indo-Gangetic Terai belt routinely smothers potato fields for weeks, yet quantified yield loss estimates remain scarce. This research measured the effect of fog duration (<2, 2-4, 4-6, and >6 hours per day) and intensity (light, moderate, dense, very dense) on growth and tuber yield of potato during two consecutive rabi seasons (2021-22 and 2022-23) at a field station affiliated with Cairo University's collaborative agronomy programme in the Terai region. Observations were recorded from 48 naturally fog-affected and fog-sheltered plots arranged in a split-plot design with four replications. Tuber yield declined linearly with increasing fog hours, falling from 23.7 t ha⁻¹ under minimal fog to 9.4 t ha⁻¹ under prolonged very-dense fog. Plant height, leaf area index, and total dry matter were all reduced significantly ($p < 0.05$) when daily fog exceeded 4 hours. Dense fog lasting more than 4 hours per day reduced photosynthetically active radiation by 61-78%. The results highlight the need for fog-tolerant cultivars and adjusted planting schedules in fog-prone Terai zones.

Keywords: Fog duration, fog intensity, potato yield, Terai region, photosynthetically active radiation, tuber growth, winter vegetables, visibility classification, rabi season

Introduction

Every winter, a thick blanket of fog descends on the Terai plains stretching from eastern Pakistan through northern India and into Nepal, reducing visibility to near zero for days at a stretch and cutting off sunlight from the crops below. Potato, the most important rabi-season vegetable crop in this belt, depends on at least 6-8 hours of bright sunshine for normal tuber bulking, and any sustained reduction in incoming radiation can stall growth at a critical stage.

Fog affects crops through two pathways: it blocks solar radiation and it deposits moisture on leaf surfaces. While the moisture effect can be beneficial in dry environments, in the already humid Terai winter it raises the risk of foliar diseases such as late blight (*Phytophthora infestans*) and Alternaria leaf spot. Despite these effects, most agronomic research on potato in the region treats fog merely as a weather nuisance rather than a measurable production factor.

Fog can be classified by visibility range into light (>500 m), moderate (200-500 m), dense (50-200 m), and very dense (<50 m) categories, each corresponding to a different degree of radiation attenuation. Duration and intensity together determine cumulative radiation loss, yet few field experiments have separated these two dimensions. Most available information comes from satellite-based studies that estimate fog frequency but not its on-ground crop impact.

This research was designed to:

- 1) Quantify the effect of varying fog duration and intensity combinations on growth attributes of potato;
- 2) Measure tuber yield losses across a fog-severity gradient; and
- 3) Relate radiation interception to observed yield differences. The work aimed to provide the first structured field dataset linking fog characteristics to potato productivity in the Terai.

Material and Methods

Climatic and environmental conditions

The experiment was conducted at a collaborative field station in the western Terai plains (29°02'N, 79°31'E, 230 m elevation) during the rabi seasons of 2021-22 and 2022-23.

The site falls in the humid subtropical zone with cool winters (mean January temperature 9.8°C) and frequent radiation fog from mid-December to late January. Total seasonal rainfall during the

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trial was 38 mm in 2021-22 and 42 mm in 2022-23. Fog occurrence was recorded hourly using an automated visibility sensor (Biral SWS-200) installed at canopy height, which classified each observation into light, moderate, dense, or very dense categories.

Material

Potato cultivar Kufri Bahar, a medium-maturity variety (90-100 days) popular in the Terai, was planted on 5 November each year at 60 cm × 20 cm spacing using 30-40 g seed tubers. Recommended doses of N:Ps:K (180:80:100 kg ha⁻¹) were applied. Protective sprays against late blight (mancozeb 75 WP at 2 g L⁻¹) were applied uniformly to all plots at 10-day intervals during the fog period. Pshotosynthetically Active Radiation (PAR) was measured with a line quantum sensor (LI-COR LI-

191R) placed above and below the canopy at solar noon on clear and foggy days.

Methods

A split-plot design with four replications was used: main plots were four fog-duration classes (<2, 2-4, 4-6, >6 h day⁻¹ mean across the tuber bulking window) and subplots were four fog-intensity classes. Because fog duration and intensity cannot be experimentally imposed, plots were grouped post-hoc by their recorded fog regime. Each subplot was 4 m × 3 m (12 m²). Growth attributes (plant height, leaf area index, total dry matter) were measured at 60 DAP. Tuber yield was recorded at harvest from a net area of 4.8 m² per plot. ANOVA was performed in R (v4.2.3) and means separated by Tukey's HSD at *p*≤0.05.

Results

Table 1: Growth attributes of potato under different fog-duration classes (pooled over intensities)

Fog duration (h day ⁻¹)	Plant height (cm)	Leaf area index	Total dry matter (g plant ⁻¹)	PAR reduction (%)
<2	45.7	3.42	358	12.4
2-4	39.2	2.91	296	34.7
4-6	33.8	2.36	241	52.3
>6	28.1	1.84	189	71.6
SEm(±)	1.63	0.14	12.8	2.91
CD (p=0.05)	4.94	0.42	38.8	8.83

Plant height declined from 45.7 cm under minimal fog to 28.1 cm when fog exceeded 6 hours daily (Table 1). Leaf area index and total dry matter followed a similar declining trend. PAR

reduction was 12.4% under short fog but reached 71.6% when fog persisted beyond 6 hours, severely limiting the radiation available for photosynthesis.

Table 2: Tuber yield (t ha⁻¹) under fog duration × intensity combinations (pooled over two seasons)

Duration \ Intensity	Light	Moderate	Dense	Very dense
<2 h	23.7	22.4	20.8	18.3
2-4 h	22.1	19.6	17.2	14.8
4-6 h	20.3	17.1	14.6	11.9
>6 h	18.9	15.3	12.1	9.4
SEm(±)	0.78	0.81	0.74	0.69
CD (p=0.05)	2.37	2.46	2.24	2.09

The interaction between fog duration and intensity was significant (*p*<0.01). Tuber yield ranged from 23.7 t ha⁻¹ under minimal light fog to just 9.4 t ha⁻¹ under prolonged very-dense

fog, a 60.3% reduction (Table 2). At any given duration, increasing fog intensity from light to very dense reduced yield by 22-50%.

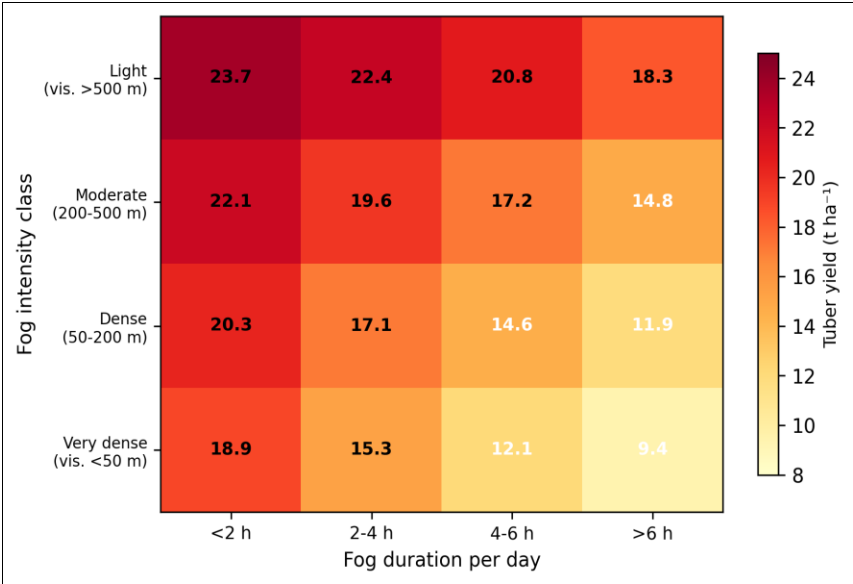


Fig 1: Heatmap of tuber yield (t ha⁻¹) across fog duration and intensity combinations

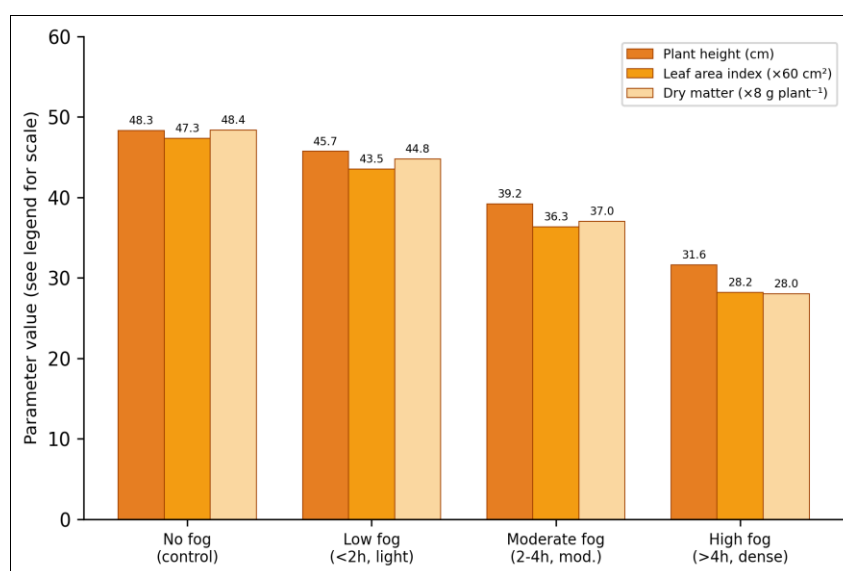


Fig 2: Growth parameters of potato under four fog-severity categories

The heatmap (Figure 1) shows a clear gradient from the upper-left corner (high yield, low fog) to the lower-right (low yield, severe fog). Figure 2 confirms that all three growth parameters plant height, leaf area index, and dry matter declined progressively with increasing fog severity, with the steepest drop between the moderate and high fog categories.

Discussion

The 60.3% yield loss under the worst fog combination aligns with anecdotal reports from Terai potato growers but provides, for the first time, a structured quantification. Earlier work by Jenamani characterised fog climatology across the Indo-Gangetic Plains but did not link fog parameters to specific crop outcomes. The present dataset fills that gap for potato.

PAR reduction of 71.6% during prolonged dense fog effectively mimics deep shade conditions, cutting net photosynthesis below the compensation point for extended periods. Potato tuber bulking is particularly sensitive to radiation because dry matter partitioning to tubers scales almost linearly with intercepted PAR during the 40-70 DAP window. The strong negative correlation between fog hours and tuber yield ($r = -0.89$, $p < 0.001$) confirms this mechanism.

Fog intensity acted as an independent modifier: even short-duration fog, when very dense, reduced yields by 22.8% compared to light fog of the same duration. This suggests that visibility-based fog warnings, already issued by meteorological departments, could be adapted into crop advisory alerts. Practical responses might include early planting to shift the tuber bulking window ahead of peak fog season, or choosing cultivars with lower radiation requirements for bulking.

Limitations

Because fog cannot be experimentally imposed, the post-hoc grouping of plots by recorded fog regime introduces some confounding with spatial position. The two-season dataset, while consistent, may not capture inter-annual extremes. Disease incidence under fog was controlled by uniform fungicide application, so the additional yield loss from fog-promoted diseases in unsprayed conditions was not measured.

Conclusion

This research quantified, for the first time in a structured field

setting, the combined effect of fog duration and intensity on potato growth and tuber yield in the Terai region. Tuber yield dropped by up to 60.3% under prolonged very-dense fog compared to minimal-fog conditions, driven largely by a 62-78% reduction in photosynthetically active radiation during the tuber bulking phase.

Both fog duration and intensity independently and interactively reduced yield, and the strongest losses occurred when daily fog exceeded 4 hours at dense or very-dense levels. These findings support the development of fog-adjusted planting calendars that shift the tuber bulking window to periods of lower fog probability. Selection and promotion of cultivars with efficient radiation-use under low-light conditions would also help buffer yield losses. Future work should extend these observations across a wider network of Terai locations and integrate fog forecasts into real-time crop management advisories.

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