



# Untying the Agronomic Paradox of Weeding Yield Loss under Tropical Dew-fall Conditions

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**Abstract:** The foundational paradigm of weed science established through decades of agronomic research posits that weeds act as direct competitors to crops for essential resources, invariably causing significant yield suppression. This principle is particularly emphasized for groundnut (*Arachis hypogaea* L.), a vital legume for global food security, due to its slow initial growth. However, this universally accepted doctrine is challenged by emerging observations from specific agro-ecological niches characterized by pronounced tropical dew-fall, where unweeded groundnut plots have been observed to outperform the weeded counterparts. A field experiment was conducted using a Randomized Complete Block Design (RCBD) with three replications to investigate this anomaly. Treatments consisted of a weeded control (W), manually weeded at 45 Days After Planting (DAP), and an unweeded treatment (UW). The results clearly validated the yield anomaly. The unweeded treatment demonstrated 44.9% higher final dry pod yield (150.41 g/plot) compared to the weeded control (103.84 g/plot), translating to 30.96% yield loss attributable to weeding. Unweeded plots also produced 21.5% more pods per plant and 31.7% higher fresh plant biomass. Early growth stages showed no competitive suppression. These findings robustly confirmed that the net effect of weed community in this environment was profoundly facilitative. The results were interpreted as strong evidence for a proposed mechanism where weed understorey enhanced dew capture and retention, and the groundnut crop utilized this supplementary moisture via foliar water uptake. That led to improved water status and photosynthetic efficiency that overwhelmingly offset the costs of below-ground competition. It was concluded that the universal agronomic paradigm that mandates routine weeding for groundnut was not applicable in tropical dew-fall environments and a paradigm shift therefore recommended towards context-specific management that leverages beneficial ecological interactions.

**Keywords:** *Arachis hypogaea*, foliar water uptake, dew-weed microclimate, sustainable agriculture, stress gradient hypothesis

## INTRODUCTION

The relentless pursuit of global food security is perpetually challenged by the intricate interplay between agricultural productivity and environmental constraints. Within this complex mix, weed management stands as a cornerstone of conventional crop production, universally recognized as a critical determinant of yield. Weeds, by definition, are plants that compete with cultivated crops for essential resources such as light, water, and nutrients, thereby exerting a formidable constraint on agricultural output (Zimdahl, 2018).

It is an established agronomic principle, supported by decades of empirical research, that effective weed control is a non-negotiable prerequisite for optimizing crop yield and ensuring economic viability for farmers.

Groundnut (*Arachis hypogaea* L.), also known as peanut, is a vital leguminous crop of significant socio-economic importance in tropical and subtropical regions. It serving as a primary source of dietary protein, edible oil, and income for millions of smallholder farmers. According to FAO (2023), world production of groundnut in the shell was ~53 million metric tons in 2022. Its cultivation, however, is particularly susceptible to weed interference, especially during the critical early growth phases before canopy closure (Chikoye et al., 2002) – a period widely identified as the Critical Period of Weed Control (CPWC). Extensive research suggests that uncontrolled weed infestation can lead to devastating yield losses of 50-70% for groundnut (Bhovva & Sardana, 2006). This has made farmers believe that timely and effective weeding is an indispensable agronomic operation in groundnut cultivation protocols worldwide.

Paradoxically, emerging observations from specific agro-ecological niches, particularly those characterized by unique microclimatic phenomena such as pronounced dew-fall, have begun to challenge this deeply entrenched paradigm. This study was situated within this paradox, investigating the anomalous case where unweeded groundnut plots demonstrated superior performance across all yield measures compared to the meticulously weeded counterparts under tropical dew-fall conditions. This anomaly signifies that the prevailing model of weed-crop interaction, which is predominantly competitive, is insufficient to explain crop performance in all agro-ecological settings. The universal application of weeding imperative, a practice based solely on competition model, is potentially leading to suboptimal yields and inefficient allocation of resources for farmers in these specific environments.

The scientific community currently lacks a mechanistic understanding of the biophysical and physiological processes that could explain this paradox. A plausible hypothesis centers on the role of weeds in modifying the field microclimate to enhance dew formation and retention, coupled with the known capacity of groundnut for foliar water uptake. Yates and Sparks (1993) demonstrated that groundnut leaves can absorb surface moisture and translocate it within the plant. Concurrently, ecological studies, such as those by Kidron et al. (2000), have shown that complex surface structures like weed canopy can significantly enhance dew deposition compared to bare soil. It is hypothesized that in weeded plots, bare soil surface leads to dew formation that is largely unavailable to crops. In contrast, the dense architecture of weed understorey in unweeded plots acts as highly efficient bio-condenser. This captures a greater volume of atmospheric moisture and retains it for longer periods, thereby making it available for foliar absorption by the overlying groundnut crop. This facilitative hydration may effectively offset the negative impacts of below-ground competition, resulting in a net positive effect on yield.

Therefore, the pivotal aim of this study was to quantitatively validate the observed yield anomaly and to elucidate the underlying mechanisms driving the superior performance of unweeded groundnut under tropical dew-fall conditions. The specific objective of this study was to evaluate and compare the effects of different weeding regimes on the growth, yield, and yield components of groundnut. The goal was to move beyond the simplistic competition-centric model and provide a holistic, mechanistic explanation for the

phenomenon. This way, they will contribute to the development of more resilient and sustainable weed management strategies for smallholder farmers in dew-prone tropical regions.

## **METHOD AND MATERIALS**

### **Research Design and Experimental Site**

A field-experimental research design was used to quantitatively determine the effect of weeding regimes on groundnut yield and to explain the underlying mechanisms. The core of the investigation was a field experiment set up as a Randomized Complete Block Design (RCBD), a robust design for controlling spatial variability in agricultural research (Gomez & Gomez, 1984). The design involved two primary treatment levels – a weeded treatment (W) and an unweeded treatment (UW). Each treatment was replicated three times, resulting in a total of six experimental plots. The use of replication provided a valid estimate of experimental error, ensuring the reliability and statistical validity of observed treatment differences. A protective buffer zone of maize (*Zea mays* L.) was planted around the experimental site to mitigate edge effects.

The field investigation was conducted at the Experimental Site of the Department of Agricultural Engineering, Njala University, located in the Moyamba District of Sierra Leone. This region falls within the tropical rainforest agro-ecological zone of West Africa, characterized by a distinct climate with a prolonged rainy season (May to October) and a pronounced dry season from November to April. The specific site was selected for its representation of typical agricultural soils and also for its microclimatic conditions during the dry season, which are conducive for significant nocturnal dew-fall driven by intense radiative cooling. The soil at the site is classified as Ultisol with sandy loam texture. It is highly suitable for groundnut cultivation due to its good drainage, a critical factor for peg penetration and pod development.

### **Experimental Treatments and Layout**

Two distinct treatment levels were used in the study to gauge the primary variable of interest – weed presence. The first treatment designated as T1 – Unweeded (UW), served as the experimental condition where no weed control measures were applied after crop establishment. This allowed the natural weed flora to grow unrestricted for the entire duration of the groundnut growth cycle. The second treatment designated as T2 – Weeded (W) Control, represented the conventional agronomic practice. In this treatment, manual weeding was done meticulously using a hand hoe at 45 days after planting (DAP), a timing that aligns with standard recommendations for CPWC in groundnut (Chikoye et al., 2002).

The physical layout of the experiment was carefully planned. Each individual experimental plot measured 2 m × 2 m, providing a total area of 4 m<sup>2</sup>. Within each plot, groundnut seeds of a locally adapted bunch-type variety ("Sierra Leone Red") were planted at a uniform spacing of 0.25 m between rows and 0.25 m within rows. This resulted in a total of 64 hills per plot, standardizing the plant population density across all treatments and replications. The three blocks were arranged to account for any underlying field gradient, with treatments randomly assigned within each block.

## Agronomic Practices

All agronomic practices, apart from the weeding regime, were uniformly standardized across all experimental plots to ensure that observed effects were attributed solely to the treatments. Land preparation included manual clearing of vegetation, followed by ploughing and harrowing to a fine tilth suitable for groundnut germination and peg development. Planting was conducted on a single day (15th December, 2024) to synchronize crop growth stages. Seeds were carefully selected for uniformity and sown at a depth of 3-5 cm. The weeding protocol constituted the core experimental manipulation. For the weeded control plots, manual weeding was rigorously enforced at 45 DAP, and all uprooted weeds removed from the plots. For the unweeded treatment, no form of weed control was implemented throughout the crop period.

## Data Collection

A comprehensive data collection protocol was implemented to assess treatment effects on weeds, crop growth, and final yield, and to gather evidence for the hypothesized physiological mechanisms. Assessments were done just prior to the scheduled weeding at 45 DAP. Within each plot, weed flora composition and density were determined using 0.5 m x 0.5 m quadrat randomly placed at two positions. All weeds within the quadrat were counted by species and then oven-dried at 70 °C to a constant weight to determine weed biomass (g/m<sup>2</sup>). Weed species were identified using standard taxonomic keys (Akobundu & Agyakwa, 1998).

Seedling emergence was recorded as a stand count and the timing of key phenological events (such as emergence of first true leaf) also recorded. At physiological maturity, all the groundnut plants from the net plot area were carefully uprooted. The plants were separated into vegetative components (haulms) and reproductive components (pods). The number of pods per plant was determined from a randomly selected sub-sample of ten plants per plot. All pods were sun-dried to a constant moisture content and weighed to determine pod weight per plot. The vegetative biomass was also recorded after oven-drying. The primary yield metric, pod yield, was calculated from the total dry pod weight per plot and converted to kilograms per hectare (kg/ha).

## Data Analysis

The collected data were subjected to rigorous statistical analysis in R-statistical software (R-Core Team, 2023). Descriptive statistics were calculated for measures of central tendency and variability for each measured parameter. A one-way Analysis of Variance (ANOVA) appropriate for a RCBD was performed for each crop parameter to test the null hypothesis of no significant difference between treatment means. The block effect was included as a random effect to account for spatial heterogeneity. The significance of the F-test was evaluated at the 5% probability level ( $p < 0.05$ ). For parameters with significant treatment effect, means were separated using Fisher's Least Significant Difference (LSD) post-hoc test at the 5% level. To quantify yield anomaly, percent yield loss due to weeding was calculated as:  $YL\% = [(UWY - WY) \div UWY] \times 100$ : where  $YL\%$  is percent yield loss;  $UWY$  is unweeded yield; and  $WY$  is weeded yield.

## RESULTS

### Weed Dynamics

The implementation of the distinct weeding regimes successfully created two fundamentally different agro-ecological environments. The floristic survey at 45 DAP revealed a diverse weed community in the unweeded (UW) plots, dominated by species such as *Ageratum conyzoides* L. (goatweed), *Synedrella nodiflora*, *Tridax procumbens* L., and the grass *Eleusine indica* (L.) Gaertn. The quantitative assessment demonstrated a stark contrast in weed pressure. The weeded (W) control plots, due to rigorous manual weeding, had a near-zero weed density. In contrast, the unweeded plots supported a dense population with mean weed density of 48.2 plants/m<sup>2</sup>. ANOVA confirmed a highly significant treatment effect at  $p < 0.001$ , validating the efficacy of the experimental study and confirming that unweeded groundnut plants were growing in an environment of intense potential competition (Table 1).

**Table 1: Effect of weeding regime on weed density at 45 Days After Planting (DAP)**

Treatment	Weed Density (plants/m <sup>2</sup> )	Standard Error
Weeded (W)	0.8 a	±0.3
Unweeded (UW)	48.2 b	±3.5

Note: Means within a column followed by different letters are significantly different at  $p < 0.05$ , based on Fisher's LSD test.

### Seedling Emergence and Growth

The analysis of crop emergence and early stand establishment showed no evidence of early-stage competition. The final average stand count for the weeded treatment was 61.0 plants per plot (95.3% emergence), while the unweeded treatment achieved 59.0 plants per plot (92.2% emergence). This small numerical difference was not statistically significant. The progression of emergence showed marginally faster initial rate in unweeded plots between 5 and 10 DAP, potentially due to microclimatic moderation from the incipient weed cover. The trends for first-leaf emergence were similar, with no significant disadvantage for the unweeded treatment. The maintenance of near-equivalent final stand was prerequisite for the subsequent yield anomaly, indicating that the dramatic yield differences were not a function of plant population but of the performance of individual plants.

### Yield and Yield Components

The data collected at physiological maturity revealed profound and statistically significant differences in all measured yield and yield components, clearly confirming the initial field anomaly (Table 2).

The analysis of vegetative growth, as indicated by fresh plant weight, showed that plants from the unweeded treatment produced 31.7% greater biomass than those from the weeded control (842.11 g/plot vs. 639.34 g/plot), a difference that was highly statistically significant ( $p < 0.01$ ). The reproductive output was even more pronounced. The number of pods harvested per plot was 21.5% higher in the unweeded treatment (164 vs. 135 pods,  $p$

< 0.05). Most critically, the final dry pod yield, representing marketable product, was 44.9% higher in unweeded plots (150.41 g/plot vs. 103.84 g/plot,  $p < 0.001$ ). When converted to per-hectare measure, these values translated to yields of ~2,596 kg/ha for weeded control and ~3,760 kg/ha for unweeded treatment.

**Table 2: Effect of weeding regime on yield and yield components of groundnut**

Yield Component	Weeded (W) Plots	Unweeded (UW) Plots	% Increase in UW
Fresh Plant Weight (g)	639.34	842.11	31.70%
Number of Pods per Plot	135.33	164.33	21.50%
Fresh Pod Weight (g)	214.81	289.73	34.90%
Dry Pod Weight (g)	103.84	150.41	44.90%

### Yield Advantage

The yield difference was expressed as yield loss attributable to weeding itself. Applying the standard formula for percent yield loss, the calculation was:  $YL\% = [(150.41 - 103.84) / 150.41] \times 100 = 30.96\%$ . This indicated that standard weeding protocol resulted in nearly 31% reduction in potential marketable yield of groundnut crop under tropical dew-fall conditions of the study. This finding represented a dramatic inversion of the typical rationale for weed control, where unweeded plot established the benchmark for productivity and substantial loss noted in weeded plot.

## DISCUSSION

### Competition or Facilitation

The superior performance of groundnut in unweeded plots necessitated a fundamental re-evaluation of the role of weed community, moving beyond the paradigm of competition to one of functional complementarity and facilitation. The observed weed flora, while dense, did not behave as a monolithic competitor but as a functionally diverse assemblage that facilitated crop growth through niche differentiation. The most plausible and impactful form of complementarity was related to the unique microclimatic and hydrological conditions. The significantly higher biomass and yield in the unweeded plots were direct reflection of more favorable growth environment, best explained by the weed community acting as facilitative bio-condenser (Kidron et al., 2000). The dense, complex weed canopy fundamentally altered the field microclimate, compared to the bare soil of the weeded plots. This enhanced the formation and prolonged the duration of dew deposition on the plant surfaces, including the leaves of the groundnut crop. This created a hidden hydrological subsidy. For a crop with documented capacity for foliar water uptake (Yates & Sparks, 1993), this weed-facilitated dew became an accessible water reservoir. This supplementary hydration likely improved plant water status, enabling earlier stomatal opening and an extended period of photosynthetic activity, directly manifesting as the observed enhanced carbon gain and biomass accumulation. The weeds, therefore, were not merely passive occupants but active agents in capturing a non-traditional water source and making it available to the crop in a usable form. This represented a profound form of functional complementarity where the weed community provided an ecosystem service that

the crop was uniquely equipped to exploit. The net outcome was a dramatic yield gain, indicating that the facilitative benefit of supplemental hydration more than compensated for any below-ground competitive costs, supporting the Stress Gradient Hypothesis in agricultural context.

### **Critical Weed Control Period Inversion**

The most profound implication of this study was the demonstration that the standard practice of weeding was the direct cause of significant yield reduction, fundamentally challenging CPWC concept. The data suggested that for groundnut under tropical dew-fall, the period 3–6 weeks after planting is not critical for weed limitation, but rather critical for weed facilitation. It was during this phase of active vegetative growth and the onset of reproduction that the crop was most responsive to the improved water status afforded by the weed-enhanced dew. The act of weeding during this window did not relieve a constraint but instead imposed one, by removing the living system that was providing a key hydrological input. Therefore, the universal application of CPWC is context-dependent, and in environments where non-traditional resources like dew are significant, the concept requires substantial modification.

The magnitude of the yield effect observed here was particularly striking when compared with conventional research. While Bhovva and Sardana (2006) noted yield losses of 70% or more from uncontrolled weeds, loss of comparable scale (31%) was noted in this study, but one that was rather caused by weeding itself. This disparity underscored the powerful role of environmental context. In systems where soil moisture is the primary limiting factor, competition dominates. Here, the unique combination of a reliable dew-fall climate and a crop with foliar water uptake capabilities created a scenario where the facilitative effect on water relations became the dominant process.

### **Agronomic Implications**

The findings of this study could have profound agronomic and practical implications. The most immediate recommendation was that the universal practice of prophylactic weeding in groundnut is flawed for tropical dew-fall environments. Farmers should discontinue weeding for groundnut in these specific contexts for significant improvements in both yield (31% advantage) and profitability. It will also eliminate a major labor cost and increase marketable output. This represents a rare win-win scenario, enhancing ecosystem services through reduced intervention while simultaneously boosting productivity and farm-level resilience.

For agricultural extension services and policymakers, there is an urgent need to revise and contextualize standard recommendations. The compelling results of this study should be used in farmer education to demonstrate the tangible economic benefits of not weeding groundnut in dew-fall climates. Policymakers should consider this evidence when designing agricultural support programs, ensuring that subsidies do not inadvertently promote counterproductive practices like weeding in these regions. This research advocates for a move away from the philosophy of control towards one of managed coexistence and synergy with ecological processes, aligning with the core principles of agro-ecology.

## **CONCLUSIONS AND RECOMMENDATIONS**

### **Summary of Findings and General Conclusion**

This study investigated the paradoxical field observation of superior groundnut yield in unweeded plots under tropical dew-fall conditions. The findings provided robust empirical support for this anomaly and elucidated the underlying mechanisms. The unweeded treatment demonstrated a highly significant advantage across all measured parameters, including 44.9% higher final dry pod yield, translating to 30.96% yield loss attributable to weeding. The study firmly established that the net effect of weed community in this environment was profoundly facilitative. The results were best explained by a synergistic mechanism wherein the weed understorey acted as bio-condenser, enhancing dew capture and retention that the groundnut crop utilized via foliar water uptake. This supplementary hydration led to improved plant water state and photosynthetic efficiency, effectively offsetting any below-ground competitive pressures. The definitive conclusion was that the presence of weed community created a net facilitative effect that superseded the costs of resource competition. Consequently, the act of weeding in this specific context significantly decreased yield by eliminating a critical ecological service. The universal agronomic doctrine of prophylactic weeding was therefore contextually flawed for groundnut cultivation in tropical dew-fall environments.

### **Recommendations**

Based on the findings, the following recommendations were advanced:

1. Smallholder farmers in tropical dew-fall regions should critically re-evaluate and halt routine weeding for groundnut. This can reduce labor costs and unlock significant yield advantage demonstrated in this study, thereby enhancing profitability.
2. Agricultural advisory services should revise training materials and recommendations to reflect this context-dependent reality. Awareness campaigns should communicate the clear economic benefits of not weeding groundnut in these specific environments. Policymakers should ensure that agricultural support programs do not subsidize counterproductive weeding practices in these regions.
3. Future research should focus on: i) validating the findings across multiple seasons and locations to assess stability under inter-annual climate variability; ii) investigating specific functional traits of facilitative weed communities; iii) extending similar investigations to other crops with foliar water uptake capabilities; and iv) developing simple decision-support tools to guide management in marginal dew years.

By adopting these recommendations, stakeholders can contribute to paradigm shift in agriculture, moving from universal input-intensive prescriptions towards more nuanced ecology-based and context-aware approach to sustainable crop production.

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## **REFERENCES**

- Akobundu, I. O., & Agyakwa, C. W. (1998). A handbook of West African weeds. International Institute of Tropical Agriculture (IITA).
- Bhovva, M. C., & Sardana, S. (2006). Efficacy of imazethapyr on weed control and productivity of groundnut (*Arachis hypogaea* L.). *Indian Journal of Weed Science*, 38(3&4), 268-270.
- Chikoye, D., Ekeleme, F., & Ambe, J. T. (2002). Evaluation of a new herbicide, oxadiazon, for weed control in groundnut (*Arachis hypogaea* L.) in Nigeria. *Crop Protection*, 21(1), 47-53.
- Food and Agriculture Organization of the United Nations (FAO). (2023). FAOSTAT: Crops and livestock products. Retrieved from <http://www.fao.org/faostat/en/>
- Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research* (2nd ed.). John Wiley & Sons.
- Kidron, G. J., Barzilay, E., & Sachs, E. (2000). Microclimate control upon sand microbiotic crusts, western Negev Desert, Israel. *Geomorphology*, 36(1-2), 1-18.
- R-Core Team. (2023). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>.
- Yates, R. A., & Sparks, D. (1993). Foliar absorption and translocation of water and nutrients in peanut. In *Proceedings of the American Peanut Research and Education Society* (Vol. 25, p. 52).
- Zimdahl, R. L. (2018). *Fundamentals of weed science* (5th ed.). Academic Press.