



Effects of Enriched Paper Mill Sludge Compost on Growth and Yield of Quinoa (*Chenopodium quinoa* Willd.)

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Abstract

Recycling industrial by-products such as paper mill sludge into organic fertilizers represents a sustainable approach to enhancing crop physiological performance and yield. Quinoa (*Chenopodium quinoa* Willd.), known for its adaptability and nutritional value, was used to evaluate these effects. A pot experiment under field conditions compared enriched paper mill sludge compost (COF) with cattle manure, chemical fertilizer, and an unfertilized control on quinoa (cv. Titicaca). All treatments were applied at an equivalent rate of 2% (w/w). Plant height, shoot dry weight, and seed yield were assessed as key physiological and productivity indicators. COF application significantly improved all measured traits, resulting in superior vegetative growth, biomass accumulation, and seed yield compared to other treatments. Enhanced growth and yield under COF suggest improved assimilate production and allocation during reproductive development. These findings highlight the applied potential of enriched paper mill sludge compost as a value-added organic amendment for sustainable crop production.

Keywords: Quinoa; Paper mill sludge compost; Plant growth; Biomass; Seed yield.

Introduction

Sustainable agriculture seeks to improve plant physiological efficiency while reducing environmental impacts through resource recycling. Adequate nutrient supply supports photosynthesis, biomass accumulation, and assimilate transfer to grains, ultimately enhancing crop yield (Barber, 1984). Recycling industrial by-products such as paper mill sludge into organic amendments offers a practical solution to waste management while sustaining plant growth through gradual nutrient release (Mao et al., 2022).

Quinoa (*Chenopodium quinoa* Willd.), a stress-tolerant pseudocereal with high nutritional value, exhibits efficient carbon allocation and strong sink capacity during reproductive growth, making it suitable for evaluating fertilizer effects on plant performance (Askegaard et al., 2004). Previous studies indicate that organic amendments derived from wastes can improve plant height, shoot dry weight, and grain yield by enhancing assimilate production and source-sink balance (Hermans et al., 2004; Rengel et al., 2015). This study aimed to compare enriched paper mill sludge compost (COF) with cattle manure and chemical fertilizer in terms of their effects on growth and yield-related traits of quinoa under pot conditions.

Materials and methods

An outdoor pot experiment was conducted under open-field conditions at the Chah Anari Experimental Farm, Isfahan University of Technology, Iran. Quinoa (*Chenopodium quinoa* Willd., cv. Titicaca) was grown in 5-kg plastic pots filled with a poor sandy soil (<0.5% organic matter).

Treatments consisted of a no-fertilizer control, enriched paper mill sludge compost (COF; containing approximately 50% organic matter and 10% lime, enriched with N-P-K at 5%), cattle manure, and a chemical fertilizer treatment (urea as the nitrogen source). All amendments were incorporated at 2% (w/w). The paper mill sludge was obtained from the Atrak cardboard factory and composted prior to nutrient enrichment.

Ten seeds were sown per pot and later thinned to two plants at the 10-cm growth stage. Irrigation was applied using non-saline water based on visual soil moisture status. At physiological maturity (≈80–90 days after sowing), plant height, shoot dry weight (70 °C, 72 h), and seed yield were measured. The experiment followed a completely randomized design with three replicates, and data were analyzed using ANOVA and LSD at $p \leq 0.05$.

Results and discussion

Enriched paper mill sludge compost (COF) significantly increased plant height compared with animal manure, chemical fertilizer, and the control, indicating enhanced vegetative growth under sustained nutrient availability (Figure 1C).

Shoot dry weight was highest in the COF treatment, reflecting improved carbon assimilation and biomass accumulation relative to other treatments (Figure 1B).

Seed yield was also maximized by COF application, suggesting more efficient assimilate partitioning and improved reproductive performance (Figure 1A).

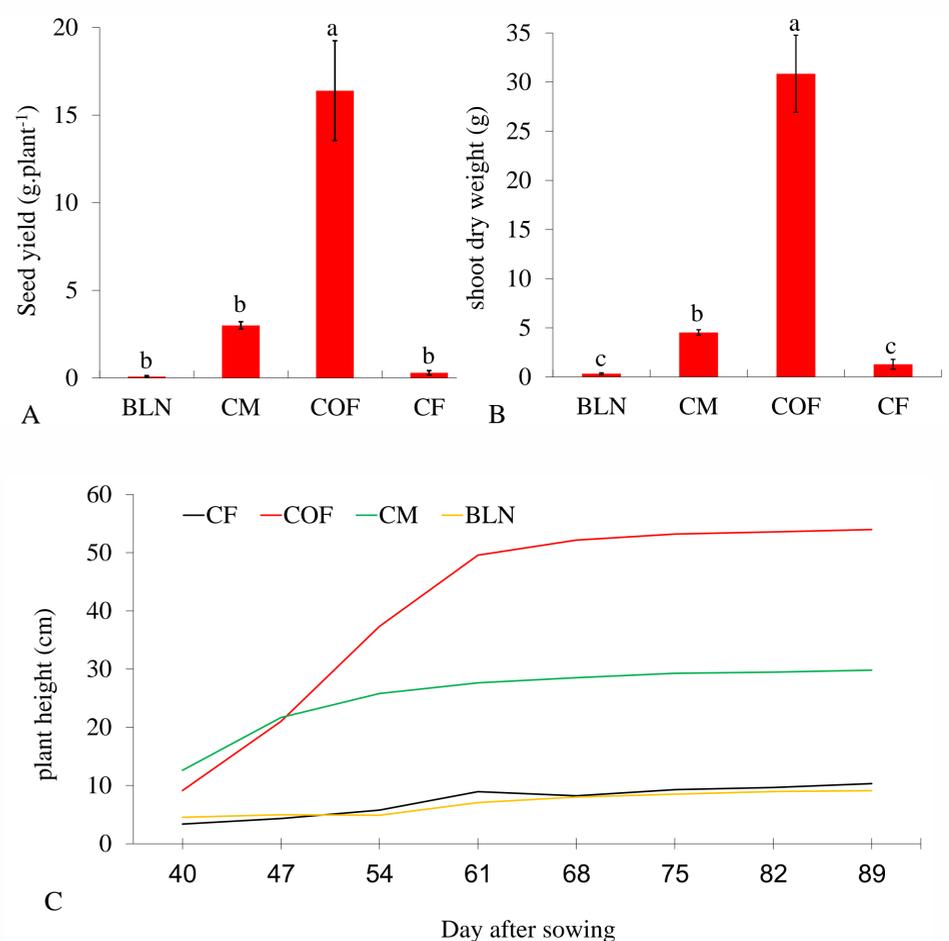


Figure 1. Effects of different fertilizers treatments on (C) plant height, (B) shoot dry weight, and (A) seed yield of quinoa. Treatments included Control (BLN), cattle manure (CM), Enriched Paper Mill Sludge Compost (COF), and Chemical Fertilizer (CF). Different letters above the bars indicate statistically significant differences based on the LSD test ($p \leq 0.05$). Error bars are calculated from the standard deviation within each treatment

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