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Effect of spacing and foliar spray on the yield of quinoa (*Chenopodium quinoa* Willd.)

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Abstract

A field experiment was carried out during the rabi season at Himalayan University, Jullang, Itanagar (Arunachal Pradesh) to evaluate the effect of different plant spacings and foliar sprays on the growth and yield of quinoa (*Chenopodium quinoa* Willd.). The study was laid out in a randomized block design with seven treatment combinations involving three spacing levels (20 cm × 10 cm, 25 cm × 15 cm, and 30 cm × 10 cm) and two foliar applications 3% moringa leaf extract and jeevamrut applied alone and in combination. Among all treatments, T₂ (20 cm × 10 cm + 3% moringa leaf extract) produced the highest panicle length (19.89 cm), test weight (2.54 g), grain yield (2.28 t/ha), stover yield (3.85 t/ha), and harvest index (38.06%). Additionally, it recorded the highest protein content (9.30%), gross returns (85,400 INR/ha), net returns (55,200 INR/ha), and benefit-cost ratio (2:82). All these improvements were statistically significant at the 5% level based on F- test values compared the control (T₁: Broadcast sowing, without any foliar spray), which showed the lowest values across parameters. These findings suggest that the use of 3% moringa leaf extract in combination with 20 cm × 10 cm spacing can significantly improve quinoa productivity and profitability in this region.

Keywords: Quinoa, moringa leaf extract, Jeevamrut, foliar spray, plant spacing, grain yield, growth parameters, test weight, B:C ratio, stover yield, stover yield, harvest index, cost ratio.

Introduction

In a world where agricultural systems face mounting pressures—from climate unpredictability to dwindling resources—there is a critical need for crops that are resilient, nutritious, and sustainable. One standout candidate is quinoa (*Chenopodium quinoa* Willd.), a pseudocereal from the Andes that has taken the global stage thanks to its impressive ability to thrive in adverse conditions and its rich nutritional profile (FAO, 2013; Jacobsen, 2003) [8, 11].

Quinoa's story stretches back over seven millennia in the high-altitude regions of Peru, Bolivia, Ecuador, and Chile, where it was revered by the Incas as the “mother grain.” After 2013 was declared the International Year of Quinoa by the UN, its cultivation spread worldwide. Currently, it grows in more than 120 countries—ranging from India and Morocco to France and the U.S.—highlighting its extraordinary capacity to adapt to drought, saline soils, and cold temperatures (Bazile *et al.*, 2016; Jacobsen, 2003) [3, 11].

Nutritionally, quinoa offers more than most traditional grains. A single sampling can contain up to 18% protein, complete with all nine essential amino acids, along with dietary fiber, healthy fats, vitamins (like B-complex and E), minerals (such as magnesium, iron, and zinc), and antioxidants (Abugoch James, 2009; Vega-Gálvez *et al.*, 2010; Filho *et al.*, 2017) [1, 21, 9]. It's also naturally gluten-free, making it a great option for those with gluten sensitivities.

In India, quinoa is currently gaining interest as a rabi-season crop, especially in arid and semi-arid regions like Rajasthan, Gujarat, and the Deccan Plateau. Yet despite its promise, our agronomic understanding of quinoa—particularly regarding optimal planting patterns and nutrient management—is still limited compared to more familiar cereal crops (Bhargava *et al.*, 2006) [4].

One technique worth exploring is to apply a foliar fertilizer that directly nourishes the leaves. Absorbed fairly quickly, they have long been considered efficient, especially in low-fertility

soils (Waraich *et al.*, 2011) ^[22]. Organic foliar sprays, including extracts of moringa, panchagavya, and jeevamrut, are also coming into limelight for promoting enzyme activity, antioxidants, and plant vigor and yield. Plant spacing is equally important, as it governs inter-plant competition for light, water, and nutrient resources, and directly influences canopy structure, airflow, and crop yield. Narrow spacing pushes for higher plant population but could hamper the performance of an individual plant; wide spacing provides much better light and diffusion but wastes good land area (Rao *et al.*, 2017) ^[18]. Due to numerous varieties of quinoa plants under various growing conditions, it is therefore very important to optimize the spacing strategy. This work evaluates the effects of different sprays together with planting spacing on the growth and yield of quinoa while implementing the research to trace out the best treatment combination that could support higher productivity and resource efficiency, thereby setting the foundation for sustainable quinoa cultivation under the subtle environmental context of Northeastern India.

Materials and Methods

Experimental Site and Climate

A field experiment entitled “Effect of spacing and foliar spray on the growth and yield of quinoa (*Chenopodium quinoa* Willd.)” was carried out during the Rabi season of 2024-25 at the Experimental Farm, Department of Agronomy, Himalayan University, Jollang, Itanagar, Arunachal Pradesh (27.074684° N latitude, 93.652878° E longitude, 320 m above mean sea level). The site lies within the Eastern Himalayan sub-tropical agro-climatic zone. The weather during the crop season was favorable, with mean temperatures ranging from 11.75°C to 22.75°C, and relative humidity between 60-75%. Meteorological data were obtained from the university weather station.

Soil Properties

The experimental plot was categorized as medium-highland, well-drained, and sandy loam in texture. Composite surface soil samples (0-15 cm) were analyzed prior to sowing. The soil was acidic in nature (pH 4.17) with organic carbon content of 1.52%, available nitrogen (612.35 kg/ha), phosphorus (4.72 kg/ha), and potassium (218.4 kg/ha). Soil texture was determined by the Bouyoucos hydrometer method (1936) and classified using the USDA soil triangle.

Experimental Design and Treatment Structure

The experiment was laid out in a Randomized Block Design (RBD) with seven treatments and three replications, totaling 21 plots. Each plot measured 3 m × 3 m (9 m²), with appropriate irrigation and drainage channels. Treatments were combinations of three spacing levels and two foliar sprays (Moringa extract and Jeevamrut), as detailed below:

Treatment	Spacing	Foliar spray
T ₁	control	control
T ₂	20 cm x 10 cm	Moringa leaf extract @ 3%
T ₃	20 cm x 10 cm	Jeevamrut
T ₄	25 cm x 15 cm	Moringa leaf extract @ 3%
T ₅	25 cm x 15 cm	Jeevamrut
T ₆	30 cm x 10 cm	Moringa leaf extract @ 3%
T ₇	30 cm x 10 cm	Jeevamrut

Crop Management

An indigenous quinoa variety was used. Seed viability was assessed by paper towel method, and germination was 92%. The field was ploughed, leveled, and laid out according to the experimental plan. Sowing was done manually on 4th November 2024, with seeds placed 2-3 cm deep. Thinning and gap filling were completed at 15 DAS. Manual weeding was performed at 25, 45, and 75 DAS, and irrigation was applied as needed to avoid moisture stress. Moringa leaf extract (3%) was prepared by blending fresh leaves with distilled water and filtering the suspension through muslin cloth. Jeevamrut was prepared using cow dung (10 kg), cow urine (10 L), jaggery (2 kg), pulse flour (2 kg), and a handful of local soil, fermented for 5-7 days in shade and stirred twice daily. Both foliar sprays were applied at 30 and 60 DAS using a knapsack sprayer.

Observations Recorded

Only yield attributes and economic traits were recorded at crop maturity:
Panicle Length (cm): Measured from the base to the tip on five plants per plot.
Test Weight (g): Weight of 1000 clean, dried grains recorded using an analytical balance.
Grain Yield (t/ha): Grain from net plot was sun-dried, cleaned, and weighed; yield was expressed in tonnes per hectare.
Stover Yield (t/ha): Dry biomass remaining after grain removal, recorded and converted to t/ha.

Harvest Index (%): = (Grain Yield / (Grain + Stover Yield)) × 100

Protein Content (%): Estimated using the Micro-Kjeldahl method (AOAC, 1965). Nitrogen (%)
Was multiplied by 6.25: Protein (%) = N (%) × 6.25

Economic Analysis

The economics of each treatment was calculated on a per hectare basis including
Cost of cultivation (INR/ha) Gross returns (INR/ha)
Net returns (INR/ha)

Benefit:Cost ratio (B:C) = Gross return / Cost of cultivation

Statistical Analysis

Data were subjected to Analysis of Variance (ANOVA) as per RBD structure, following standard procedures. The significance of treatment effects was evaluated using F-test at 5% level, and Critical Difference (CD) was computed for mean separation when treatment differences were significant.

Results and Discussion

A. Effect of Spacing and foliar Spray on panicle Length (cm) of Quinoa

Panicle length was significantly affected by the interaction of spacing and foliar spray treatments (Table 1). The maximum length (19.89 cm) was recorded in T₂ (20×10 cm + moringa leaf extract @ 3%), followed closely by T₅ (25×15 cm + Jeevamrut) at 19.80 cm. The shortest panicle (17.24 cm) was observed in the control (T₁).

The improved performance of T₂ may be attributed to bioactive compounds in moringa, such as cytokinins and antioxidants, which promote reproductive growth. Similar enhancements in quinoa panicle length with 3% MLE were reported by Junaid *et al.* (2023)^[12] and Rashid *et al.* (2021)^[19].

T₅ showed comparable results, likely due to Jeevamrut's

microbial activity and nutrient enhancement. Moderate spacing (25×15 cm) reduced competition and improved light interception, contributing to better inflorescence growth. Pattar & Biradar (2022)^[15] and Meena *et al.* (2020)^[13] also noted spacing-related improvements in quinoa yield traits.

Table 1: Effect of Spacing and foliar Spray on panicle Length (cm) of Quinoa.

Treatment Symbol	Treatment combination	Panicle Length(cm)
T ₁	Control	17.24
T ₂	20 cm x 10 cm + moringa leaf extract @ 3%	19.89
T ₃	20 cm x 10 cm + jeevamrut	19.46
T ₄	25cm x 15cm + moringa leaf extract @ 3%	18.48
T ₅	25cm x 15cm + jeevamrut	19.80
T ₆	30 cm x 10 cm + moringa leaf extract @ 3%	19.13
T ₇	30 cm x 10 cm + jeevamrut	19.64
	F-Test	S
	C.D at 0.5%	0.36
	S.Em(±)	0.78

B. Effect of Spacing and foliar Spray on Test weight (g) of Quinoa

Test weight was significantly influenced by the interaction between spacing and foliar sprays (Table 2). Treatment T₂ showed the greatest test weight (2.54 g), which is 0.01 g higher than in T₅ followed by (Germination stage 25 × 15 cm + Jeevamrut). Treatment T₁, the control, had the least test weight of 2.39 g.

Seed weight improvement under T₂ can likely be attributed to the interaction of close spacing plus Moringa leaf extract. The 20×10 cm spacing probably favors early canopy closure and better light utilization, while MLE supplies cytokinins, amino acids, and antioxidants to the plants to enhance seed filling and photosynthate partitioning. Yasmeen *et al.* (2013)^[23] reported

that MLE improved seed quality and weight through antioxidant activity and chlorophyll content enhancement.

In the same way, treatment T₅ had improved seed development by enhancing microbial activity and nutrient availability in the rhizosphere soil. Desai *et al.* (2018)^[7] argued that Jeevamrut enhanced soil biological activity, thus contributing to better formation of grains in organic farming systems.

This was well coordinated with the findings of Basra *et al.* (2011)^[2] and Fuglie (2001)^[10], who stated that application of MLE @ 3% enhances seed development through an increase in enzymatic activity and nutrient uptake.

Table 2: Effect of Spacing and foliar Spray on Test weight (g) of Quinoa.

Treatment Symbol	Treatment combination	Test weight (g)
T ₁	Control	2.39
T ₂	20 cm x 10 cm + moringa leaf extract @ 3%	2.54
T ₃	20 cm x 10 cm + jeevamrut	2.53
T ₄	25cm x 15cm + moringa leaf extract @ 3%	2.44
T ₅	25cm x 15cm + jeevamrut	2.53
T ₆	30 cm x 10 cm + moringa leaf extract @ 3%	2.50
T ₇	30 cm x 10 cm + jeevamrut	2.51
	F-Test	s
	C.D at 0.5%	0.01
	S.Em(±)	0.02

C. Effect of Spacing and foliar Spray on Grain yield (t/h) of Quinoa

“Grain yield (t/ha) was significantly affected by spacing by the interaction of foliar spray treatment (Table -3). Maximum yield of 2.28 t/ha was recorded for the treatment T₂ (20×10 cm + MLE @ 3%), followed by treatment T₅ (25×15 cm + Jeevamrut), with 2.25 t/ha. The minimum grain yield of 1.79 t/ha was recorded in the control (T₁)”.

Now tighter spacing of T₂ favored higher plant density and canopy closure, which led to a greater accumulation of photosynthates per unit area. The Moringa extract, due to its high content of cytokinins and antioxidants, improved grain

filling and source-sink efficiency, as confirmed in earlier studies by Yasmeen *et al.* (2013)^[23].

Moderate spacing in T₅ allowed optimum light penetration and root development, while Jeevamrut further supported yield enhancement by improving rhizosphere health. Rojas *et al.* (2017)^[20] reported that 25×15 cm spacing best optimizes the balance between plant density and individual plant performance in quinoa.

Hence, ensuring optimum spacing combined with organic foliar biostimulants can support the increase in quinoa grain yield under resource-efficient conditions.

Table 3: Effect of Spacing and foliar Spray on Grain yield (t/h) of Quinoa.

Treatment Symbol	Treatment combination	Grain yield (g)
T ₁	Control	1.79
T ₂	20 cm x 10 cm + moringa leaf extract @ 3%	2.28
T ₃	20 cm x 10 cm + jeevamrut	2.19
T ₄	25cm x 15cm + moringa leaf extract @ 3%	2.01
T ₅	25cm x 15cm + jeevamrut	2.25
T ₆	30 cm x 10 cm + moringa leaf extract @ 3%	2.15
T ₇	30 cm x 10 cm + jeevamrut	2.18
	F-Test	s
	C.D at 0.5%	0.03
	S.Em(±)	0.05

D. Effect of Spacing and foliar Spray on Stover yield (t/h) of Quinoa

“Stover yield of quinoa was significantly influenced by the interaction of plant spacing and foliar spray treatments (Table-4). The greatest stover yield (3.85 t/ha) was recorded under T₁ (20 × 10 cm + moringa leaf extract @ 3%), followed by T₅ (25 × 15 cm + Jeevamrut), which recorded 3.75 t/ha of stover yield, while the minimum yield of 3.20 t/ha was recorded under control”.

The higher stover yield under T₂ was due to a closer spacing that created a greater plant density; in turn, it caused higher total biomass accumulation per unit area. This was collaborative with the treatment of Moringa leaf extract containing natural cytokinins and antioxidants, which supported vegetative growth

and dry matter production. These results were in support of the findings of Yasmeen *et al.* (2013) [23], who observed increased biomass of cereal crops with the MLE treatment.

In T₅, the moderate spacing of 25 × 15 cm allowed for better light interception, air circulation, and root spread whereas Jeevamrut increased microbial activity, nutrient availability, and plant vigor, thus resulting in viable stover biomass per plant. Similar findings were documented by Desai *et al.* (2018) [7] under organic systems using Jeevamrut.

These results elucidate that beneficial foliar sprays interact well with adequate spacing to significantly increase stover yield in quinoa through the alteration of plant architecture, vegetative growth, and biomass partitioning.

Table 4: Effect of Spacing and foliar Spray on Stover yield (t/h) of Quinoa.

Treatment Symbol	Treatment combination	Stover yield (t/h)
T ₁	Control	3.2
T ₂	20 cm x 10 cm + moringa leaf extract @ 3%	3.85
T ₃	20 cm x 10 cm + jeevamrut	3.6
T ₄	25cm x 15cm + moringa leaf extract @ 3%	3.35
T ₅	25cm x 15cm + jeevamrut	3.75
T ₆	30 cm x 10 cm + moringa leaf extract @ 3%	3.45
T ₇	30 cm x 10 cm + jeevamrut	3.55
	F-Test	s
	C.D at 0.5%	0.03
	S.Em(±)	0.07

E. Effect of Spacing and foliar Spray on Harvest index (%) of Quinoa

The harvest index was affected significantly by varied spacing and foliar spray treatments (Table-5). The highest HI of 38.06% was noted in T₁ (20 × 10 cm + Moringa leaf extract @ 3%), followed by T₂ (25 × 15 cm + Jeevamrut) with 37.99% while the lowest was observed in the control of 34.40%.

The reason behind improvement in HI under T₂ was the bio-stimulant action of Moringa leaf extract that contains zeatin, antioxidants, and micronutrients. These bioactive compounds help in better translocation of assimilates from the vegetative parts to the economic yield (grain), thereby increasing biomass conversion efficiency. Similar effects of MLE on HI were also observed by Rady *et al.* (2013) [16] in which they recorded

greater partitioning of dry matter toward reproductive organs.

The slightly wider spacing in T₅ helped plants in better interception of light and served to reduce inter-plant competition, where as Jeevamrut added beneficial microbes to the rhizosphere. Both factors together aided in better nutrient absorption and reproductive development that increased harvest index. The findings from Patel *et al.* (2020) [14] and Desai *et al.* (2018) [7] corroborate the current study by showing Jeevamrut to have increased nutrient use efficiency and helped in biomass allocation.

The optimum spacing arrangement of T₂ and T₅ ensures an effective interplay of plant density and resource availability so as to discourage excessive vegetative growth but encourage grain production.

Table 5: Effect of Spacing and foliar Spray on Harvest index (%) of Quinoa.

Treatment Symbol	Treatment combination	Harvest index (%)
T ₁	Control	34.40
T ₂	20 cm x 10 cm + moringa leaf extract @ 3%	38.06
T ₃	20 cm x 10 cm + jeevamrut	36.50
T ₄	25cm x 15cm + moringa leaf extract @ 3%	37.33
T ₅	25cm x 15cm + jeevamrut	37.99
T ₆	30 cm x 10 cm + moringa leaf extract @ 3%	37.87
T ₇	30 cm x 10 cm + jeevamrut	37.69
	F-Test	s
	C.D at 0.5%	0.30
	S.Em(±)	0.66

F. Effect of Spacing and foliar Spray on Protein (%) of Quinoa

“Protein contents in quinoa grains were significantly influenced by the interaction of spacings and foliar spray treatments (Table-6)”. The highest protein content (9.30%) was recorded in T₂ (20 × 10 cm + moringa leaf extract @ 3%), followed by T₅ (25 × 15 cm + Jeevamrut) with 9.20%, and the lowest was recorded in T₁ (Control) with 8.05%.

In T₂, the high protein percentage is probably due to the bioactive compounds present in Moringa leaf extract that improves the nitrogen metabolism and synthesis of chlorophyll. This further encourages the formation of amino acids and the

synthesis of proteins. Protein quality of quinoa grains was positively influenced with MLE foliar spray, as reported by Rashid *et al.* (2021)^[19] and Junaid *et al.* (2023)^[12], who found that it improves nutritional quality and yield.

The second-highest protein content was recorded in T₅, which might be due to Jeevamrut soil amelioration, which enhances the microbial population and thus increases nitrogen availability in the rhizosphere. Carlsson *et al.* (2015)^[5] explained that appropriate spacing, in combination with nutrient enhancement, improves not only yield but also quality parameters such as protein content in quinoa.

Table 6: Effect of Spacing and foliar Spray on Protein content (%) of Quinoa.

Treatment Symbol	Treatment combination	Protein content (%)
T ₁	Control	8.05
T ₂	20 cm x 10 cm + moringa leaf extract @ 3%	9.30
T ₃	20 cm x 10 cm + jeevamrut	9.10
T ₄	25cm x 15cm + moringa leaf extract @ 3%	8.25
T ₅	25cm x 15cm + jeevamrut	9.20
T ₆	30 cm x 10 cm + moringa leaf extract @ 3%	8.50
T ₇	30 cm x 10 cm + jeevamrut	8.75
	F-Test	s
	C.D at 0.5%	0.10
	S.Em(±)	0.30

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