QUINOA

STANDARD OPERATING PROCEDURE

A FIELD GUIDE

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AEZ	Agro-ecological Zone
ARDC	Agriculture Research and Development Center
cm	Centimeters
DoA	Department of Agriculture
FAO	Food and Agriculture Organization
FYM	Farm Yard Manure
kg	Kilogram
MC	Moisture Content
MoAL	Ministry of Agriculture and Livestock
masl	meters above sea level
NPPC	National Plant Protection Center
NSSC	National Soil Service Center
PHS	Pre-Harvest Sprouting
PoP	Package of Practices
SOP	Standard Operating Procedure

1 Introduction

Quinoa (*Chenopodium quinoa* Willd) was introduced to Bhutan in 2015 with the support of the Food and Agriculture Organization (FAO) of the United Nations. The primary objective of introducing quinoa was to adapt this versatile, climate-resilient, and nutrient-dense cereal to the different growing environments and enhance the food and nutritional security of the Bhutanese people. Quinoa is known as *Ashi Heychum* in *Dzongkha, Ashi Mo* in *Sharchop* and *Rani Bethu* in *Lhotsham*. Since its introduction a decade ago, quinoa has been adapted across different agro-ecological zones in the country. The cultivation of quinoa in Bhutan is categorized into High, mid, and low-altitude zones. This Standard Operating Procedure (SOP) outlines the standard cultivation practices for the three distinct production zones. The recommendations are based on actual adaptation trials conducted by the National Quinoa Commodity Programs in collaboration with different Agriculture Research and Development Centers (ARDCs) and field experiences with farmers.

2 Quinoa production system

Since its introduction, quinoa has been widely evaluated and adapted to different agroecologies, altitudes, and crop production systems across the country. Although quinoa has been successfully harvested at altitudes up to 3000 masl in Bhutan, three distinct agro-ecologies are recommended for viable quinoa production. These are categorized as high, mid, and low, based on actual field validations. The production zones, elevation ranges, agroecosystems, and dominant crop production systems recommended for quinoa are described in Table 1.

Table 1. Production zones, elevation ranges, agroecosystems, and dominant production systems for quinoa cultivation in Bhutan

Production Zone	Elevation Range	Agro-Ecosystem	Dominant Land Use System
High Altitude	1800-2700 masl	Warm Temperate	Dryland
Mid Altitude	1200-1800 masl	Dry Subtropical Transitional Zone	Dryland
Low Altitude	600-1200 masl	Dry subtropical, Humid Subtropical	Dryland &Wetland
	100-600 masl	Wet Subtropical	Dryland &Wetland

3 Quinoa Variety

There are four varieties released by Department of Agriculture (DoA). The best variety recommended for all three production zones is Ashi Heychum-AM (*Amarilla Marangani*). However, the recommended sowing time has to be followed for each specific production zone.

4 Seed rate and sowing

High-quality and viable seeds are the most basic requirement for successful quinoa production. Quinoa seeds are small and very sensitive to moisture and temperature, requiring careful attention during sowing. The recommended seed rate is 2.5 to 3 kg/acre. Sowing quinoa seeds requires both experience and skill. When seeds are sown very shallowly, it can cause desiccation due to solar radiation and predation by birds. Deep sowing can prevent germination due to restricted growth. The recommended sowing depth is 1-3 cm. Seed can be broadcast or planted in line. When quinoa is sown in line, the recommended line spacing is 50-60 cm, with a plant-to-plant spacing of 10-20 cm, which is maintained through thinning.

5 Soil and land preparation

Quinoa requires fertile sandy-loam, loamy-sand, or loam soil for optimal growth. Quinoa can tolerate soil pH from 4.5 - 9. Quinoa does not tolerate water logging and prefers well-drained soils. The field preparation for planting quinoa is similar to that for mustard and wheat. Quinoa does not require raised beds, such as those for vegetables, or ridges, like those for potatoes. At least two ploughings are recommended to prepare a fine and well leveled seedbed for sowing. The use of power tiller and mini-tiller will enhance efficiency and fine seedbed preparation.

6 Fertilizer

Quinoa is mainly grown in marginal environments with minimal external inputs. It is typically planted as a second crop and benefits from the residual nutrients applied to the main crop. Application of a sufficient quantity of compost or well-decomposed Farm Yard Manure (FYM) is necessary. To optimize production, the application of additional nutrients is important. Based on the nutrient management trials conducted by the National Soil Service Center (NSSC), the application of NPK is recommended at the rate of 30:20:20 N:$P_2 0_5$:K kg/acre. This translates into 125 kg/acre of Suphala and 22 kg/acre of Urea. The entire dose of Suphala (125 kg/acre) should be applied as a basal dose during the land preparation. Nitrogen in the form of Urea should be top-dressed in two split doses. The first top dressing (11 kg/acre of Urea) should be done three

weeks after sowing when the crop is at the 4-6 leaf stage. This application helps in tillering and leaf development. The second top dressing (11 kg/acre of Urea) should be done at flowering or panicle initiation to support panicle development and grain filling. The application of Urea should be done carefully to avoid direct contact with plants.

7 Cropping pattern

Through adaptive trials conducted by the regional ARDCs, various cropping sequences were evaluated to integrate quinoa into farmers' traditional cropping systems. The recommended cropping patterns or sequences for the different production zones are presented in Table 2.

Table 2. Recommended cropping patterns/sequence for quinoa

Production Zone	**Production System**	**Traditional Cropping Pattern**	**Recommended Cropping Pattern**	**Main/Second Crop**
High Altitude	Dryland	Potato-fallow Potato-turnip Potato-winter wheat Potato-mustard Potato-vegetables Buckwheat-fallow Vegetables-vegetables	Quinoa-fallow Quinoa-winter wheat /barley Buckwheat–quinoa (early) Vegetables-quinoa Quinoa-peas/turnip	Main and second crop
Mid Altitude	Dryland	Potato-mustard Maize-barley Maize-vegetables Maize-mustard Chilli-vegetables	Potato-quinoa Maize-quinoa Potato+Maize-quinoa Vegetables-quinoa	Second crop
Low Altitude	Dryland	Potato-vegetables Maize-mustard Maize-maize Peanut-fallow Maize -millet Millet-millet	Maize-quinoa Peanuts-quinoa Millet-quinoa	Second crop
	Wetland	Rice-vegetables Rice-fallow Rice-wheat	Rice-quinoa (avoid waterlogged areas)	Second crop

8 Sowing time

In Bhutan, the presence of diverse agroecosystems allows for year-round cultivation of quinoa. However, the timing of sowing is critically important for successful quinoa production. Temperature, rainfall, and short-day length are the key factors that affect the successful cultivation of quinoa. In mountainous areas, the microclimate of a location is greatly influenced by the time of sowing. The challenges and the general sowing time recommended for different production zones are presented in Table 3.

Table 3. Recommended sowing time for quinoa

Production Zone	Land Use System	Main Cropping Systems	Recommended Sowing Time
High Altitude	Dryland	Potato based	Mid April-May Sowing should be done after the occurrence of the last frost
Mid Altitude	Dryland	Potato & Maize-based	Mid July – Mid August For transitional zones between dry and humid subtropical to warm temperate – Mid August-Early October
Low Altitude	Dryland	Maize based	Mid-October – Mid-November
	Wetland	Rice based	Mid-November to the First Week of December

9 Irrigation

Quinoa has low water requirement and is generally grown as rainfed crop. However, the provision of additional water at critical stages through supplement irrigation can enhance productivity. The most critical stages of moisture requirement in quinoa are seed germination, crop establishment, flowering and grain filling. It is important to provide supplement irrigation at seedling stage if dry spells occur. To prevent moisture stress which severely impacts yield, light and frequent irrigations is important. The use of sprinklers is preferred over heavy flooding, especially on drylands. Avoid water logging at all crop stages.

Germination and Establishment: Ensure adequate soil moisture (not saturated) for uniform germination and early seedling growth, especially if rainfall is insufficient post-sowing. Supplemental irrigation is crucial during the seedling stage, especially during dry spells.

Flowering and Grain Filling: To prevent moisture stress, which severely impacts yield, light, frequent irrigations (e.g., sprinkler, furrow) are preferred over heavy flooding, especially on drylands. Avoid water logging at all costs.

Cessation: Stop irrigation well before maturity (approx. 2-3 weeks before harvest) to promote drying and reduce Pre-harvest Sprouting (PHS) risk**.**

10 Weeding

Quinoa seeds germinate very quickly, but the growth is slow after germination. Weed control for quinoa crops is important when it is grown as a main crop in high-altitude areas. In mid-altitude areas, seed sowing typically occurs from July to August, when weed pressure is at its highest. Weed is not a major issue in low altitudes where quinoa is cultivated as a winter crop. Hand weeding is the only suitable weed control option available. If quinoa is sown in lines, weeder be used (Figure 2.).

11 Pests and diseases

Quinoa is not prone to many pests and disease attacks. The incidence of pests in quinoa varies depending on the cultivation time. When the crop is cultivated as the main crop in high and mid-altitude areas, the common pest observed is the Leaf miner (Diptera: Agromyzidae). In low-altitude areas, quinoa is cultivated in winter, and the common pest observed is the black bean aphid *(Aphis fabae)*.

Control Measures for Leaf Miner:

i. Remove and destroy infested leaves and plant debris to reduce populations.
ii. Practice crop rotation to break the pests' life cycles.
iii. Control weeds around crops, as they can host leaf miners.
iv. Use contact insecticides like Cypermethrin 10% EC (1 ml per liter of water) and Malathion 50% EC (2 ml per liter of water), which mainly kill adult flies. These insecticides are not effective against larvae inside the leaves.

v. To control larvae, use systemic insecticides such as Chlorantraniliprole 18.5% SC (0.3 ml per liter of water).
vi. Under organic management, a weekly spray of Neem oil 10,000 PPM (3-5 ml per liter of water) has been found effective against larvae.

Control Measures for Black Bean Aphid:

i. Eliminate alternative hosts like Chenopodium album and Sonchus near the crop.
ii. Use a strong jet of water to physically dislodge aphids from plants.
iii. Spray with oils such as horticultural mineral oil (HMO), which are less harmful to beneficial insects and effective against aphids.
iv. Use contact insecticides like Cypermethrin 10% EC (1 ml per liter of water) and Malathion 50% EC (2 ml per liter of water), which are very effective for controlling black bean aphids. Both should be applied during early infestation with good leaf coverage, especially on the undersides.

12 Maturity and harvest

The maturity of the quinoa depends on the altitude. In the high and mid-altitude production zone, quinoa matures in 150-180 days. In the low-altitude production zone, due to short day length, the crop takes 120 to 130 days to mature. The crop maturity should not coincide with the rainy season to avoid PHS. If mature quinoa panicles are exposed to rain, the seeds within the panicle sprout, which can affect grain quality. Determining the optimal time for harvest is crucial. Quinoa is ready for harvest when the leaves turn yellow or red, depending on the variety. The leaves on the panicles dry and the grains are visible within the panicles. The maturity can also be judged by squeezing the grain between two fingers. If the grains are hard to squeeze, then the crop is ready for harvest. Quinoa can be harvested manually with sickles by cutting the plants 10-15 cm above the soil. The harvested crop is sun-dried for a week before threshing.

13 Post-Harvest and Storage

The three most important post-harvest operations are threshing, winnowing, and storage. After the quinoa plants are properly dried, they should be threshed manually or with threshers to separate the grains. Once the grains are threshed, winnowing is performed manually or with grain winnowers to remove the chaff. During the process of threshing, winnowing and milling use of face mask is recommended to avoid irritation from Quinoa husk. The grains are then dried properly before storage. Grains should be stored in clean and dry environments in airtight super grain bags. The moisture content (MC) for safe storage of quinoa grain ranges from 8% to 10%.



14 Conclusion and Recommendation

This SOP is based on actual field experiences and adaptive trials conducted nationwide by the National Quinoa Commodity Program in collaboration with other ARDCs. The trials and demonstrations were conducted in all three Agro-ecological Zone (AEZs) in the different cropping seasons and finally the most suitable planting season for quinoa was recommended for different AEZs. Due to the mountainous terrain, varying specific microenvironments and cropping sequences across different locations, observation trials are necessary for more specific recommendations. When quinoa is introduced in a new location, it is recommended that farmers participate in evaluating the crop's suitability and acceptance.

The 10 most important recommendations for quinoa cultivation are summarized below:

i. Quinoa is a rain fed crop suitable in dryland and wetland, but it doesn't grow under water logging conditions.
ii. Farmers should plant the recommended varieties.
iii. Farmers should follow the recommended sowing time for different AEZs.
iv. The recommended seed rate is 2.5 to 3 kg/acre.
v. Farmers should follow the recommended land preparation practices, fertilizer application and irrigation to obtain high yield.
vi. Moisture, temperature and relative humidity is very critical to maintain seed viability.

vii. The moisture content for safe storage of quinoa seed is 8 to10%.
viii. Quinoa seeds should be dried properly and stored in air-tight super grain bags.
ix. Multi crop threshers can be used for separating quinoa grains from panicles.
x. Before consumption the removal of saponin using milling machine is necessary.

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