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Studies on seed dormancy and effect of antioxidants on growth, seed yield and quality in quinoa (*Chenopodium quinoa* willd)

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Abstract
A study on dormancy breaking methods in quinoa was conducted in the laboratory of Department of Seed Science and Technology, College of Agriculture, University of Agricultural Sciences, GKVK, Bengaluru during 2022-23. The experiment comprises of different treatments *viz.*, control, potassium nitrate (KNO3) @ 0.2%, 0.5%, 1% for 12 hr, Gibberellic Acid (GA3) @ 100 ppm, 200 ppm, 500 ppm, for 12 hr, Thiourea @ 1%, 2% for 12 hr and kinetin @ 50 ppm, 100 ppm, 200 ppm for 12 hr, Among treatments highest germination (87.25 %), mean seedling length (9.80 cm), mean seedling dry weight (8.96 mg), seedling vigour index-I (855), seedling vigour index-II (782) were recorded in treatment KNO3 @ 1 % for 12 hr and lowest (28.50 %, 7.80 cm, 6.94 mg, 222 and 198, respectively) were recorded in control. It is concluded that treatment KNO3 @ 1 % for 12 hr can break the dormancy in quinoa.

Keywords: EED dormancy, *Chenopodium quinoa*, potassium nitrate, gibberellic acid, thiourea, kinetin, seed germination, seedling vigour index

Introduction
Quinoa (*Chenopodium quinoa* willd.) is a allo tetraploid grain crop of the *Amaranthaceae* family having chromosomes number (2n = 4x = 36) with the impressive drought tolerance. Dicotyledonous annual plant grown as a grain crop primarily for its edible seeds. It is botanically a pseudo cereal, commonly called kinwa, parka, dawe, and chuppah in different regions of the world. It provides dietary minerals, dietary fibre, protein and vitamin B rich amounts above those of wheat, corn, rice or oats. It is gluten free and have low glycaemic index (GI) excellent for diabetic people. Recent years, increasing recognition of importance of quinoa and trying to substitute as major cereals. Now its gaining popularity and recognized as a “super food” for its health benefits. FAO nominated Globally 2013 as the “International year of quinoa” (Bhargava *et al*., 2006) [5]. Quinoa grain is used for human consumption and used in several food preparations like upma, breakfast, make flour, soup. While the flour is utilized in making biscuits, bread and processed food. It also provides protection against cancer and heart related diseases and also rich in minerals and nutrients. In addition, quinoa consists of higher concentration of amino acids like lysine (5.1-6.6 %), isoleucine (6.4 %), glycine (5.2 %), threonine (4.8 %), histidine (2.7 %), cysteine (2.4 %) and methionine (2.4 %) in seed (Van etten *et al*., 1963) [13]. that are deficient in cereals. About 70 thousand tons were produced in the Andean area in 2009 of which, about 40 thousand tonnes were produced by Peru, 28 thousand tons by Bolivia and 746 tons by Ecuador. Bolivia and Peru are the principal quinoa-producing nations in the world. Both of them occupy 90 % of the world's quinoa production (Anon., 2013) [2]. In India, quinoa was grown on 440 hectares of land with an average yield of 1.053 tonnes / hectare (Srinivasa Rao, 2015) [12].
However, quinoa seeds lose viability more rapidly than cereals because of the porosity in the integument, which allows a seed to easily gain or lose moisture and may initiate germination in the panicle. Quinoa seed quality is influenced by the low germination rate and reduced

vigor (Hernandez *et al.*, 2020) [7]. Dormancy is defined as an internal condition that prevents seed germination under favorable conditions. Seeds with relatively low dormancy germinate in a wider range of conditions than those with relatively high levels of dormancy and only a limited amount of information about seed dormancy in *Chenopodium* species is available. Some literature refers to seed coat importance in dormancy maintenance. Quinoa seeds undergo a natural dormancy phase, a biological mechanism crucial for its survival. Seed dormancy is a protective mechanism that prevents premature germination, ensuring the seeds remain viable until favorable conditions for growth and reproduction are met. Quinoa seeds exhibit varying levels of dormancy, influenced by genetic, environmental, and physiological factors. Understanding the intricate processes underlying quinoa dormancy is essential for agricultural practices, aiding farmers in optimizing germination methods and ensuring sustainable crop production. Delving into the complexities of quinoa dormancy unveils insights that contribute significantly to global food security and agricultural advancements.

Now a days seed industry needs as they are facing difficulty in immediate marketing of quinoa and there is no reliable recommended seed treatment to break the dormancy. However, in reality the potentiality of this crop is not fully exploited. So, farmers are more interested to cultivate this crop, since it is poor germination because of dormancy, the experiment is to understand the details of dormancy by utilizing different dormancy breaking treatments.

Material and methods

The present investigation was carried out in the Department of Seed Science and Technology, University of Agricultural Sciences, GKVK, Bengaluru during the year 2022 to 2023. The seeds of quinoa variety himshakti were collected from AICRP on potential crop, UAS, GKVK, Bengaluru. For seed dormancy breaking treatments *viz.*, potassium nitrate (KNO3) @ 0.2%, 0.5%, 1% for 12 hr, Gibberellic Acid (GA3) @ 100 ppm, 200 ppm, 500 ppm,

for 12 hr, Thiourea @ 1%, 2% for 12 hr and kinetin @ 50 ppm, 100 ppm, 200 ppm for 12 hr treatments were employed in the experiment for standardization of seed dormancy breaking treatments. The seeds were put to germination in top paper by using blotters. The germination test was carried out in walk in seed germinator. Seed quality parameters *viz.*, germination, mean seedling length, mean seedling dry weight, seedling vigour index-I and II were evaluated.

Observations recorded

Seed germination (%)

The germination test was conducted by using top of the paper method as per the ISTA rules. One hundred seeds from each treatment were drawn at random in four replicates and seed sample were incubated in a germination chamber maintained at 25±1 °C and 90 per cent relative humidity. Germinated seedlings were evaluated on 8th day as final count and percentage germination was expressed based on number of normal seedlings. (Anon., 2021) [3].

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds used for the test}} \text{X } 100$$

Mean seedling length (cm)

Ten normal seedlings were selected randomly from each treatment on the day of final count and seedling length was measured from the tip of shoot to root tip and the mean length was recorded and expressed as mean seedling length in centimeters.

Mean seedling dry weight (mg)

Ten normal seedlings used for measuring shoot and root length will be taken in a butter paper and dried in hot air oven maintained at 80 ^{0}C temperatures for 24 h, Then the seedlings will be removed and allowed to cool in desiccators for 45 minutes before weighing on an electrical balance. The average will be calculated and expressed as mean seedling dry weight in milligram (mg) (Anon., 2021) [3].

Seedling vigour index-I

The seedling vigour index-I was computed by multiplying per cent germination and mean seedling length (cm) and expressed as a whole number (Abdul-Baki and Anderson, 1973) [1].

Seedling vigour index-I = Germination (%) x Mean seedling length (cm)

Seedling vigour index-II

Seedling vigour index-II was determined by multiplying per cent germination with total seedling dry weight (Abdul Baki and Anderson, 1973) [1]

Seedling vigour index-II = Germination (%) x Mean seedling dry weight (mg)

Results and discussion

Below are the experimental findings obtained after conducting a statistical analysis on the seed quality parameters of quinoa under different treatments. The significance of the results has been tested using standard statistical methods, and they have been comprehensively discussed in the context of the available situations.

Seed germination (%)

The data on percentage of germination was influenced by different dormancy breaking treatments in quinoa seeds are represented in the Table 4.1. There was a significant variation in germination percentage among different dormancy breaking treatments. The seeds treated with potassium nitrate (KNO3) @ 1% (T4) recorded maximum (87.25 %) germination followed by seeds treated with thiourea at 2 per cent T9 (81.50 %). Whereas, the control (T1) showed significantly minimum (28.50 %) germination. The germination per cent of normal seedlings was recorded (87.25 %) when seeds were treated with potassium nitrate (KNO3) @ 1%. The KNO3, which increases the germination of photo-dormant seeds. According to Bewley and Black (1982) [4], KNO3 raises the ambient oxygen level available for citric acid cycle. Similar results were reported in *Panicum maximum* by Previero *et al.* (1996) [11]. KNO3 may be helpful for reactivation of metabolic process of seeds. This compound may cause biosynthesis of auxin, which ultimately triggers the growth of embryo (Khan *et al.*, 1999) [8]. Nitrites promotes seed germination by inhibition of H2O2 decomposition by catalase and help in the leakage of abscisic acid (Hendricks and Taylorson, 1974) [6].

Mean seedling length (cm)

Data on mean seedling length as influenced by different dormancy breaking treatments are presented in Table 4.2. Seeds treated with potassium nitrate (KNO3) @ 1% (T4) showed significantly maximum (9.80 cm) mean seedling length which was on par with thiourea 2 per cent T9 (9.71 cm). However, minimum (7.80 cm) mean seedling length was observed in control (T1). This might be due to KNO3 had a very favourable effect on increasing seed germination, seedling growth and increased activity of nitrate reductase, catalase, alkaline lipase, and phosphatase enzymes, more auxin biosynthesis, elongation in cambium cells and increased division of root cells, subsequent increase of seedling length causing increased embryo growth (Kwon *et al*., 2020; Lara *et al*., 2014) [9, 10].

Mean seedling dry weight (mg)

Data related to mean seedling dry weight differed significantly by the impact of different dormancy breaking treatments are presented in Table 4.2. Among different dormancy breaking treatments seeds treated with potassium nitrate (KNO3) @ 1% (T4) showed highest (8.96 mg) mean seedling dry weight followed by thiourea 2 per cent T9 (8.36 mg). However, control (T1) recorded lowest (6.94 mg) mean seedling dry weight. Seedling dry weight increased due to increase in root length, shoot length and total seedling length.

Table 1: Standardization of dormancy breaking treatments on seed germination (%), abnormal seedlings (%), Hard seeds (%) and dead seeds (%) in quinoa

Treatments	Seed germination (%)	Abnormal seedlings (%)	Hard Seeds (%)	Dead seeds (%)
T1: Control	28.50	19.25	39.25	13.00
T2: Potassium Nitrate (KNO3) @ 0.2%	69.50	9.50	17.00	4.00
T3: Potassium Nitrate (KNO3) @ 0.5%	72.75	8.50	15.00	3.75
T4: Potassium Nitrate (KNO3) @ 1%	87.25	3.50	6.25	3.00
T5: GA3 @ 100 ppm	63.50	5.25	21.25	10.00
T6: GA3 @ 200 ppm	66.00	9.00	16.00	9.00
T7: GA3 @ 500 ppm	67.00	6.25	18.75	8.00
T8: Thiourea @ 1%	70.75	6.00	15.50	7.75
T9: Thiourea @ 2%	81.50	6.00	8.75	3.75
T10: Kinetin @ 50 ppm	55.50	9.00	27.25	8.25
T11: Kinetin @ 100 ppm	63.25	8.75	17.25	10.75
T12: Kinetin @ 200 ppm	65.75	9.00	16.25	9.00
S. Em±	0.58	0.20	0.36	0.16
CD (P=0.05)	1.66	0.58	1.04	0.46
CV (%)	1.76	4.89	3.99	4.29

***NS:** Non-significant

Seedling vigour index-I

Data pertaining to seedling vigour index-I as influenced by different dormancy breaking treatments are presented in the Table 2. Different dormancy breaking methods significantly influence the seedling vigour index-I. Among them, seeds treated with potassium nitrate (KNO3) @ 1% (T4) showed highest (855) seedling vigour index-I followed by thiourea 2 per cent T9 (791). However, control (T1) reported lowest (222) seedling vigour index-I. This might be due to enhancement of germination and seedling length.

Seedling vigour index-II

Data on seedling vigour index-II significantly influenced by different dormancy breaking treatments are presented in Table 2. Among them, seeds treated with potassium nitrate (KNO3) @ 1% (T4) recorded highest (782) seedling vigour index II followed by seeds treated with thiourea 2 per cent T9 (681). Whereas, the lowest (198) seedling vigour index-II was found in control (T1). This might be due to increase in percent germination and seedling dry weight.

Table 2: Standardization of dormancy breaking treatments on mean seedling length (cm), mean seedling dry weight (mg), seedling vigour index-I and seedling vigour index- II in quinoa

Treatments	Mean seedling length (cm)	Mean seedling dry weight (mg)	Seedling vigour index-I	Seedling vigour index-II
T1: Control	7.80	6.94	222	198
T2: Potassium Nitrate (KNO3) @ 0.2%	8.85	8.03	615	558
T3: Potassium Nitrate (KNO3) @ 0.5%	9.20	8.26	669	600
T4: Potassium Nitrate (KNO3) @ 1%	9.80	8.96	855	782
T5: GA3 @ 100 ppm	8.35	7.05	530	447
T6: GA3 @ 200 ppm	8.81	7.57	582	499
T7: GA3 @ 500 ppm	8.87	7.45	594	499
T8: Thiourea @ 1%	9.10	7.94	644	562
T9: Thiourea @ 2%	9.71	8.36	791	681
T10: Kinetin @ 50 ppm	7.85	6.84	435	380
T11: Kinetin @ 100 ppm	8.16	6.96	516	440
T12: Kinetin @ 200 ppm	8.39	7.54	552	496
S. Em±	0.09	0.08	9.20	8.38
CD (P=0.05)	0.27	0.24	26.40	24.04
CV (%)	2.20	2.45	3.15	3.27

***NS:** Non-significant

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