INFLUENCE OF NUTRIENT MANAGEMENT AND SEED BIO-PRIMING TECHNIQUES ON SEED YIELD AND QUALITY IN QUINOA (*Chenopodium quinoa* Willd.)

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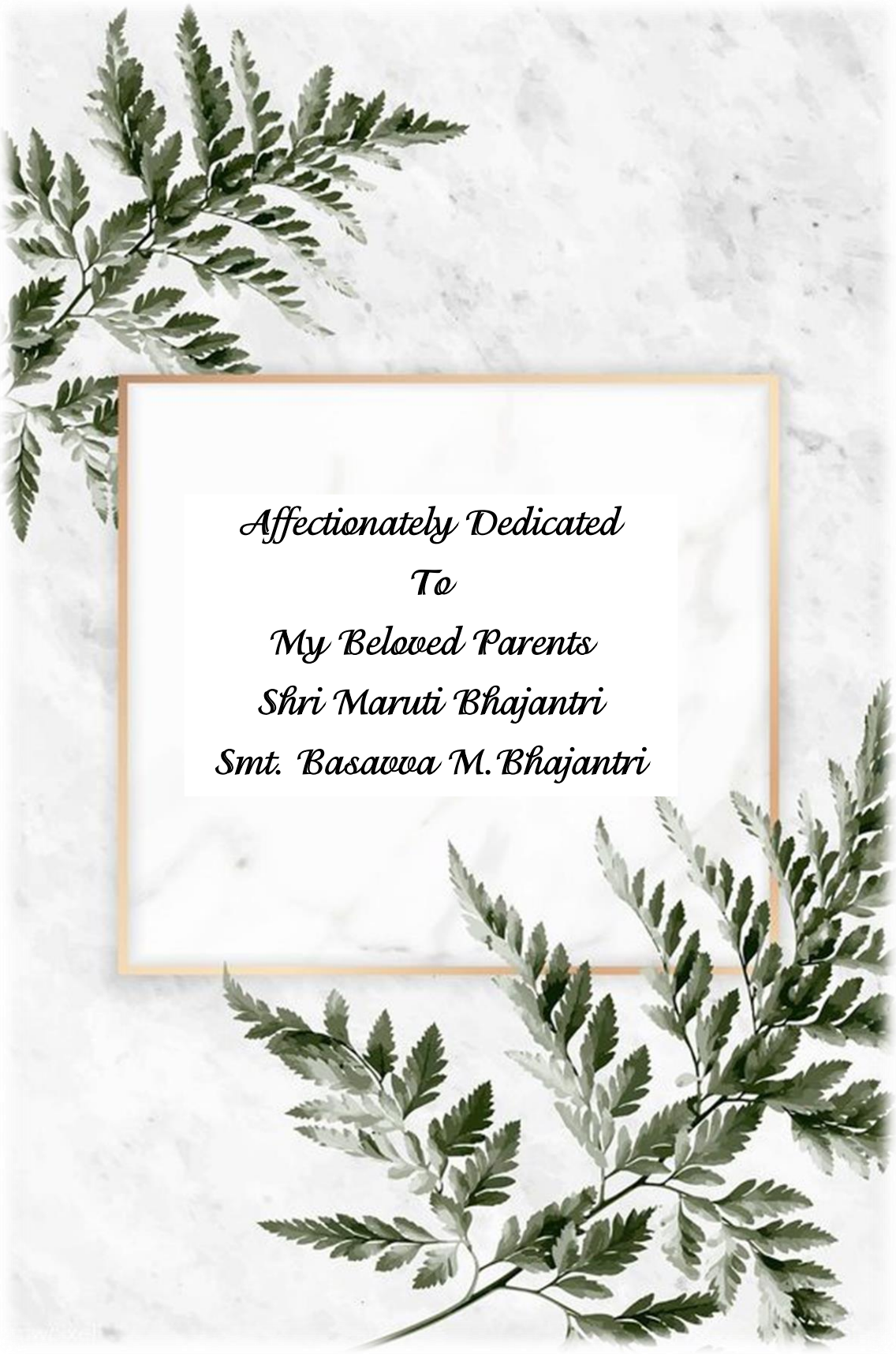
Affectionately Dedicated
To
My Beloved Parents
Shri Maruti Bhajantri
Smt. Basawva M. Bhajantri

DEPARTMENT OF SEED SCIENCE AND TECHNOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE

CERTIFICATE

This is to certify that the thesis entitled "**INFLUENCE OF NUTRIENT MANAGEMENT AND SEED BIO-PRIMING TECHNIQUES ON SEED YIELD AND QUALITY IN QUINOA *(Chenopodium quinoa* Willd.)**" submitted by **Mr. RAMESH BHAJANTRI, ID No. PALB 8337** for award of the degree of **MASTER OF SCIENCE (Agriculture)** in **SEED SCIENCE AND TECHNOLOGY** of the University of Agricultural Sciences, Bangalore. This is a *bona-fide* record of research work carried out by him during the period of his study in this University, under my guidance and supervision, and the thesis has not previously formed the basis for the award of any degree, diploma, associate-ship, fellowship or other similar titles.

Bengaluru
February, 2021

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(T. M. RAMANAPPA)

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INFLUENCE OF NUTRIENT MANAGEMENT AND SEED BIO-PRIMING TECHNIQUES ON SEED YIELD AND QUALITY IN QUINOA (*Chenopodium Quinoa* Willd.)

RAMESH BHAJANTRI

ABSTRACT

A field experiment was conducted at the Indian Institute of Seed Science, MAU Regional Station, Gandhi Krishi Vigyana Kendra, Bengaluru during *Rabi*-2019 to study the influence of nutrient management and seed bio-priming techniques on seed yield and quality in quinoa. Experiment was laid out in a factorial RCBD with 3 replications and 12 treatments combination compromising four nutrient levels and three seed bio-priming treatments. Among different treatment, nutrient levels of 80:50:50 NPK kg ha^{-1}+ DAP spray (2 %) and seeds primed with *Pseudomonas fluorescens* (20 %) recorded the highest plant height at 30, 60 DAS and harvest (36.10,88.83,91.80 cm respectively), total number of panicles $plant^{-1}$ was (13.10), panicle length of main stem was (32.57 cm), panicle dry weight $plant^{-1}$was(27.13 g), seed yield $plant^{-1}$ was (6.97 g), seed yield $plot^{-1}$ was (1.52 kg), seed yield $ha^{-1}$was (14.93 q ha^{-1}). Seed quality parameters *viz*, was recorded maximum at treatment of 80:50:50 NPK kg ha^{-1}+ DAP spray 2 % with seeds treated with *pseudomonas fluorescens* (20%) recorded 1000 seed weight was (2.99 g), germination (90.50 %) mean seedling length was (11.97 cm), mean seedling dry weight was (0.735 mg), seedling vigour index- I was (1038), seedling vigour index- II was(639). For standardization of seed sieve size a sieve size of 1.40 mm considered as optimum for processing quinoa seeds for more recovery (94.64 %) with seed quality parameter.

February, 2021

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ಕ್ವಿನೋವಾ (ವರದಕ್ಕಿ– ಚಿನೊಪೊಡಿಯಮ್ ಕ್ವಿನೋವಾ) ಬೆಳೆಯಲ್ಲಿ ಬೀಜದ ಇಳುವರಿ ಹಾಗೂ ಬೀಜ ಗುಣಮಟ್ಟದ ಮೇಲೆ ಪೋಷಕಾಂಶಗಳು ಮತ್ತು ಜೈವಿಕ ಬೀಜ ಲೇಪನಗಳ ಪ್ರಭಾವ

ರಮೇಶ ಭಜಂತ್ರಿ

ಪ್ರಬಂಧ ಸಾರಾಂಶ

ಕ್ವಿನೋವಾ (ವರದಕ್ಕಿ–ಚಿನೊಪೊಡಿಯಮ್ ಕ್ವಿನೋವಾ) ಬೆಳೆಯಲ್ಲಿ ಬೀಜದ ಇಳುವರಿ ಹಾಗೂ ಬೀಜ ಗುಣಮಟ್ಟದ ಮೇಲೆ ಪೋಷಕಾಂಶಗಳು ಮತ್ತು ಜೈವಿಕ ಬೀಜ ಲೇಪನ ಪ್ರಭಾವ ಕುರಿತಾದ ಅಧ್ಯಯನವನ್ನು ೨೦೧೯ ರ ಹಿಂಗಾರು ಹಂಗಾಮಿನಲ್ಲಿ ಕ್ಷೇತ್ರ ಪ್ರಯೋಗವನ್ನು ಭಾರತೀಯ ಬೀಜ ವಿಜ್ಞಾನ ಸಂಸ್ಥೆ ಪ್ರಾದೇಶಿಕ ಕೇಂದ್ರ ಜಿ.ಕೆ.ವಿ.ಕೆ., ಬೆಂಗಳೂರು ಇಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಈ ಪ್ರಯೋಗವನ್ನು ಯಾದ್ರಿಚ್ಛಿಕ ಸಂಪೂರ್ಣ ಅಳವಡಿಸಿ ವಿನ್ಯಾಸದಡಿಯಲ್ಲಿ ನಾಲ್ಕು ಪೋಷಕಾಂಶಗಳು ಮತ್ತು ಮೂರು ಜೈವಕ ಬೀಜ ಲೇಪನಗಳೊಂದಿಗೆ ಬೀಜೋಪಚಾರ ಮಾಡಲಾಗಿರುತ್ತದೆ. ಹಾಗೂ ವಿಭಿನ್ನ ಉಪಚರಿಕೆಯ ಸಂಯೋಜನೆಗಳಲ್ಲಿ ೮೦:೫೦:೫೦ ಎನ್.ಪಿ.ಕೆ .(ಕೆ.ಜಿ /ಹೆಕ್ಟೇರ್) + ಶೇ.೨ ಡಿ.ಎ.ಪಿ ಸಿಂಪರಣೆ ಮತ್ತು ಸ್ಯೂಡೋಮೊನಾಸ್ ಫ್ಲೋರೊಸೆನ್ಸ್ ನೊಂದಿಗೆ ಸಂಸ್ಕರಿಸಿದ ಬೀಜಗಳಲ್ಲಿ ಹೆಚ್ಚಿನ ಸಸ್ಯ ಎತ್ತರ (೩೬.೧೦, ೮೮.೮೩, ೯೧.೮೦ ಸೆಂ. ಮೀ ಕ್ರಮವಾಗಿ) ೩೦, ೬೦ ಮತ್ತು ಕೊಯ್ಲಿನ ದಿನದ ಬೆಳೆಯಲ್ಲಿ ದಾಖಲಾಗಿರುತ್ತದೆ ಮತ್ತು ಮುಖ್ಯ ಕಾಂಡದಲ್ಲಿ ಗರಿಷ್ಠ ತೆನೆಯ ಉದ್ದ (೩೨.೫೭ ಸೆಂ.ಮೀ), ತೆನೆಯ ಒಣತೂಕ (೨೭.೧೩ ಗ್ರಾಂ. ಪ್ರತಿಗಿಡಕ್ಕೆ), ಬೀಜ ಇಳುವರಿ (೬.೯೭ ಗ್ರಾಂ. ಪ್ರತಿಗಿಡಕ್ಕೆ), ಬೀಜ ಇಳುವರಿ ಪ್ರತಿ ತಾಕುವಿಗೆ (೧.೫೨ ಕೆ.ಜಿ) ಮತ್ತು ಬೀಜದ ಇಳುವರಿ (೧೪.೯೩ ಕ್ವಿಂ. ಪ್ರತಿ ಹೆಕ್ಟೇರ್) ಕಂಡುಬಂದಿರುತ್ತುದೆ. ಬೀಜದ ಗುಣಮಟ್ಟ ನಿಯತಾಂಕಗಳಲ್ಲಿ ಹೆಚ್ಚಿನ ಪೋಷಕಾಂಶಗಳ ಲೇಪನ ೮೦:೫೦:೫೦ ಎನ್.ಪಿ.ಕೆ. (ಕೆ.ಜಿ /ಹೆಕ್ಟೇರ್) + ಶೇ.೨ ಡಿ.ಎ.ಪಿ ಸಿಂಪರಣೆ ಮತ್ತು ಸ್ಯೂಡೋಮೊನಾಸ್ ಫ್ಲೋರೊಸೆನ್ಸ್ ಬೀಜೋಪಚಾರದಿಂದ ಹೆಚ್ಚಿನ ಬೀಜದ ತೂಕ (೨.೯೯ ಗ್ರಾಂ), ಗರಿಷ್ಠ ಶೇಕಡಾವಾರು ಮೊಳಕೆಯ ಪ್ರಮಾಣ ೯೦.೫೦, ಸರಾಸರಿ ಮೊಳಕೆಯ ಉದ್ದ (೧೧.೯೭ ಸೆಂ.ಮೀ), ಸರಾಸರಿ ಮೊಳಕೆಯ ಒಣ ತೂಕ (೦.೭೩೫ ಮಿ.ಗ್ರಾಂ.), ಮೊಳಕೆಯ ಸಾಮರ್ಥ್ಯ ಸೂಚ್ಯಕ–I (೧೦೩೮) ಮತ್ತು ಮೊಳಕೆಯ ಸಾಮರ್ಥ್ಯ ಸೂಚ್ಯಕ–II (೬೩೯) ಕಂಡುಬಂದಿದೆ. ಸಂಸ್ಕರಣೆಯಲ್ಲಿ ಗರಿಷ್ಠ ಭೌತಿಕ ಶುದ್ಧ ಕ್ವಿನೋವಾ (ವರದಕ್ಕಿ) ಬೀಜ ಸಾಮಗ್ರಿಯನ್ನು ವಿಂಗಡಿಸಿ ಅಂತಿಮವಾಗಿ ಪಡೆಯಲು ೧.೪೦ ಮಿ.ಮಿ ರಂಧ್ರದ ಜರಡಿಯು ಅತ್ಯಂತ ಸೂಕ್ತವೆಂದು ಪರಿಗಣಸಲಾಯಿತು.

ಫೆಬ್ರವರಿ, ೨೦೨೧

ಬೀಜ ವಿಜ್ಞಾನ ಮತ್ತು ತಂತ್ರಜ್ಞಾನ ವಿಭಾಗ **ಪಿ. ವೆಂಕಪ್ಪ**

ಕೃ.ವಿ.ವಿ., ಜಿ.ಕೆ.ವಿ.ಕೆ., ಬೆಂಗಳೂರು–೬೫ **(ಪ್ರಧಾನ ಸಲಹೆಗಾರರು)**

"Influence of nutrient management and seed bio-priming techniques on seed yield and quality in Quinoa (*Chenopodium quinoa* Willd.)"

RAMESH BHAJANTRI, PALB 8337

Department of seed science and technology

Introduction

- Quinoa (*Chenopodium quinoa wild.*) is an annual herbaceous plant belonging to family *Amaranthaceous* and having its origin in the Pacific slopes of the Andes in South America.
- . As per United Nations Organization for Agriculture and Food, the quinoa grain is the only vegetable food that provides all amino acids essential to the life of humans in optimum quantities and is comparable with milk.
- The protein content ranges from 7.47 to 22.08 per cent. The oil content is 1.8 to 9.5 per cent and rich in essential fatty acids. The digest ability of quinoa protein is more than 80 percent. Quinoa also contain natural anti-oxidants like αtocopheral (5.3 mg), γ-tocopheral (2.6mg) in 100 g seed and phytoestrogens that prevent chronic diseases such as osteoporosis, breast cancer, heart diseases and other feminine problems caused by lack of oestrogen during the menopause. Hence FAO nominated 2013 as International year of Quinoa (Bhargava *et al.*, 2006).

Objectives

- To study the nutrient management in seed yield and quality
- To evaluate the seed bio-priming techniques on seed yield and quality
- To standardize the grading sieves to upgrade the seed quality

Material and methods

Crop	: Quinoa
variety	: EC 507740
Number of treatments	: 12
Number of replications	: 3
Season	: *Rabi*-2019
Design	: FRCBD
Gross Plot Size	: 2.0 m× 3.0 m
Location	: IISSc, GKVK, Bangalore
Seed rate	: 10 kgha^{-1}

Treatment details

Factor I: Nutrient management (N)

N_1 : 60:40:20 NPK kg ha^{-1}

N_2 : 80: 50: 50 NPK kg ha^{-1} + 2 % ferrous sulphate spray at flowering

N_3 : 80: 50: 50 NPK kg ha^{-1} + 2 % DAP spray at pre-flowering

N_4 : 125 kg neem cake ha^{-1} + 1250 kg vermicompost ha^{-1} + 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1} + 10 kg Azospirillum ha^{-1}

Factor II : Seed bio-priming (P)

P_1 : Control – No priming

P_2 : Seed priming with *T. harzianum* (1.5 %)

P_3 : Seed priming with 20 % *liquid Pseudomonas fluorescence* (6hr)

Results

Table 1: Number of panicles plant $^{-1}$), Panicle weight (g) , seed yield (kg ha^{-1}), 100 seed weight (g) and germination (%), vigour index-I as influenced by nutrients levels and seed bio-priming treatments Quinoa *cv.* EC50774

Treatments	Number of panicles plant^{-1}	Panicle weight (g)	Seed yield per ha^{-1}	Germination (%)	1000 seed weight (g)	Vigour index-I
Nutrient levels (N)						
N_1: 60:40:20 NPK kg ha^{-1}	9.42	20.15	12.37	84.49	2.83	943
N2: 80: 50 : 50 NPK kg ha^{-1} + 2 % $Feso_4$ spray	11.05	22.40	13.98	88.00	2.88	960
N3: 80 : 50 : 50 NPK kg ha^{-1} + 2 % DAP spray	12.25	25.31	14.47	89.82	2.91	1007
N4: 125 kg Neem cake ha^{-1}+ 1250 kg Vermicompost ha^{-1} + 10 PSB ha^{-1} + 10 kg Azospirillum ha^{-1}+ 10 KSB ha^{-1}	10.01	20.51	13.85	85.25	2.79	924
S.Em ±	0.42	2.35	0.18	0.77	00.5	26.38
CD (P = 0.05)	1.25	NS	0.52	2.28	NS	NS
Priming treatments (P)						
P_1 : Control	10.06	21.73	13.38	86.26	2.82	932
P_2 : Seed priming with T. harzianum (1.5 %)	10.46	20.89	13.41	87.11	2.86	985
P_3 : Seed priming with 20 % liquid Pseudomonas fluorescens (6hr)	11.53	23.65	14.21	87.41	2.87	990
S.Em ±	0.37	2.03	0.15	0.67	0.04	22.84
CD (P = 0.05)	1.08	NS	0.45	NS	NS	NS
Interaction (NXP)						
N_1P_1	9.67	14.80	11.38	82.83	2.83	925
N_1P_2	8.47	24.33	12.37	85.83	2.80	985
N_1P_3	10.13	21.33	13.37	84.83	2.86	921
N_2P_1	10.73	25.93	14.17	87.87	2.83	919
N_2P_2	10.93	20.20	13.50	89.07	2.92	978
N_2P_3	11.50	21.07	14.27	89.17	2.89	985
N_3P_1	11.07	23.67	14.33	89.17	2.81	961
N_3P_2	12.60	25.13	14.17	88.17	2.93	1023
N_3P_3	13.10	27.13	14.93	90.50	2.99	1038
N_4P_1	8.77	22.53	13.67	85.20	2.82	925
N_4P_2	9.87	13.93	13.63	85.40	2.80	953
N_4P_3	11.40	25.07	14.27	85.17	2.77	896
S Em ±	0.74	4.07	0.31	1.34	0.09	45.69
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
CV (%)	12.64	31.93	3.96	2.68	6.06	8.25

- Nutrient treatment 80:50:50 NPK kg ha^{-1} + 2 % DAP spray with seeds treated with pseudomonas fluorescence (N_3P_3) recorded higher plant height at 30 DAS (36.10 cm), 60 DAS (88.83 cm), at harvest (91.80 cm), total number of panicles plant^{-1} (13.10), panicle length of main stem (32.57 cm), panicle dry weight plant^{-1} (27.13 g), seed yield plant^{-1} (6.97 g), seed yield plot^{-1} (1.52 kg), bulk seed yield (14.93 q/ha).
- Nutrient treatment 80:50:50 NPK kg ha^{-1} + 2 % DAP spray with seeds treated with *pseudomonas fluorescens* (N_3P_3) recorded test weight (2.99 g), germination (90.50 %), mean seedling length (11.97 cm), mean seedling dry weight (0.735 mg), seedling vigour index- I (1038), seedling vigour index- II (639), electrical conductivity (0.062 dScm^{-1}), dehydrogenase activity (0.535 A_{480} nm).

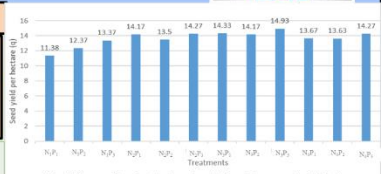

Fig 1 Influence of nutrient levels and seed bio-priming on seed yield ha^{-1}

Plate 1 Influence of nutrient levels and seed bio-priming on panicle length of main stem

Plate 2 Influence of nutrient levels and seed bio-priming on seed germination

Plate 3 General view of experimental plot

Discussion

This is because the nutrients present in them are easily absorbed by the plants and unlike the nutrients present in organic fertilizers, It is an established fact that nitrogen promotes the vegetative growth consequently up to an optimum levels resulting in more yields. Phosphorous and potassium are also responsible for better growth, maturity and seed yield. All these three nutrients affected positively on the performance of plant and yield contributing traits which resulted in higher seed yield plant^{-1}. These findings are in agreement with the results of Jyothi *et al.* (2016) in foxtail millet and Bhomte *et al.* (2016) in little millet.

The priming with *P. fluoresces* was evident in improving the seed yield and yield attributing factors in pearl millet by Raj *et al.* (2004). The enhancement in the seedling growth noticed in this study could be attributed to suppression of deleterious microorganisms and pathogens; production of plant growth regulators such as gibberllins, cytokonins and indole acetic acid , which increased the availability of minerals and other ions and more water uptake (Ramamoothy *et al.* 2000).

Summary

Among various nutrient management practices, integrated use of inorganic fertilizer and DAP spray *viz.*, application of inorganic fertilizer 80:50:50 NPK kgha^{-1} + 2 % DAP spray at pre-flowering and seed treated with 20 % *Pseudomonas fluorescens* recorded significantly higher panicle dry weight (27.13 g), seed yield per plant (6.97 g), seed yield per plot (1.44 kg), 1000 seed weight (1.52 g), seed yield per hectare (14.93 q).

Reference

KARYOTIS, T., ILIADIS, C., NOULAS, C. AND MITSIBONAS, T., 2003, Preliminary research on seed production and nutrient content for certain quinoa varieties in a saline-sodic soil. *J. Agro.Crop Scie.*, **189**(6): 402-408.

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LIST OF ABBREVATIONS

%	:	Per cent
@	:	At the rate of
*	:	Significant
CD	:	Critical difference
CV	:	Coefficient of Variation
cm	:	Centimeter
DAS	:	Days after sowing
et al	:	Group of workers
Fig	:	Figure
g	:	Gram
ha	:	Hectare
i.e.,	:	That is
t	:	tonnes
kg	:	Kilogram
mg	:	Milligram
m	:	Meter
q	:	quintals
h	:	Hours
NS	:	Non-significant
^{o}C	:	Degree Celsius
RDF	:	Recommended dose of fertilizers
S. Em±	:	Standard error of mean
Viz.,	:	Namely
RH	:	Relative Humidity
Temp	:	Temperature

I INTRODUCTION

Quinoa (*Chenopodium quinoa* willd.) is an annual herbaceous plant belonging to family *Amaranthaceae* and having its origin in the Pacific slopes of the Andes in South America. It was cultivated and used by the Inca (ruling class) people since 5,000 B.C. It is cultivated in the world in an area of 1.26 lakh hectares with a production of 103 thousand tonnes. In India, quinoa is being cultivated in an area of 440 hectares with an average yield of 1053 tonnes (Srinivas *et al.*, 2015). As per United Nations Organization for Agriculture and Food, the quinoa seed is the only vegetable food that provides all amino acids essential to the life of humans in optimum quantities and is comparable with milk. The protein content ranges from 7.47 to 22.08 per cent. The oil content is 1.8 to 9.5 per cent and rich in essential fatty acids like linoleate and linolenate. The digestability of quinoa protein is more than 80 percent. Quinoa also contain natural anti-oxidants like α-tocopherol (5.3 mg), γ-tocopherol (2.6 mg) in 100 g seed and phytoestrogens that prevent chronic diseases such as osteoporosis, breast cancer, heart diseases and other feminine problems caused by lack of estrogen during the menopause. Hence, FAO nominated 2013 as "International year of Quinoa".

Quinoa is a pseudo cereal that has been cultivated in the Andean region for thousands of years. It is an annual broad-leaved plant, 1 to 2 m tall with deep penetrating roots and can be cultivated from sea level up to an altitude of 3800 m, pH range of 6 to 8.5 and temperature from sub-tropical to tropical and humid areas. The plant shows tolerance to frost, salinity and drought. It has the ability to grow on marginal soils. Quinoa grain is highly nutritious due to its outstanding protein quality and wide range of minerals and vitamins. The grain protein is rich in amino acids like lysine and methionine that are deficient in cereals. The grain is used to make flour, soup, breakfast, cereal and alcohol, while the flour is utilized in making biscuits, bread and processed food. Quinoa starch having small grains and high viscositycan be exploited for various industrial applications. The crop is self-pollinated with low out crossing rates. Emasculation and hybridization are cumbersome due to small size of the flowers, but male sterility in some cultivars and gynomonoecious breeding system may help breeding research in this crop. Quinoa's ability to produce high-protein grains under ecologically extreme conditions makes it important for the

diversification of future agricultural systems, especially in high-altitude area of the Himalayas and North Indian Plains. It is assumed quantitative short day species where the length of the vegetative phase not only depends on latitude of the origin and depends on the day length (Risi, 1984).

Quinoa is rich in protein, dietary fiber, vitamin B and dietary minerals, which are higherthan above those in wheat, corn, rice and oats. It is gluten free, after harvest, the seeds are processed to remove the bitter tasting of seed coat. Quinoa grain is used for human consumption and used in several food preparations like upma, whole grain as rice, pulao etc. Quinoa makes rich with nutrients and good for diabetic patients. It also provides protection against cancer and heart related diseases. The quinoa consists of high protein (14.1 g/100 g) higher than cereals and millets and with higher concentration of isoleucine, glycine, cysteine, lysine (5.1-6.4 %), hystidine and methionine (0.4-1.0 %). It also contains lower amounts of Mn, Fe, Cu, Zn and Ca. In addition, quinoa seed also rich in thiamine (0.4 mg), riboflavin (0.39 mg), vitamin C (16.4 mg), folic acid (78.1 mg) and carotene (0.39 mg) in 100 g seed.

The seed yield of the quinoa is generally influenced by agronomical, physiological and seed production factors involving potentiality of varieties and nutrient management by following proper package of practices in addition to inherent capacity of cultivar. Crop nutrients are the elements, which are essential for growth healthy and vigorous plants. They initiate all processes that are vital for crop development. Therefore, plant needs nutrients throughout its growing cycle.

Integrated nutrient approaches on yield and quality of crops is reported by many researchers from India and elsewhere in different crops. Nitrogen plays an important role in vegetative growth of plants and finally increases biomass and yield (Sandhya *et al*., 2017).

As the fertilizer, level increased the seed vigour index also increased. This is mainly due to application of fertilizer dose enhance the accumulation of higher quantities of seed carbohydrates, proteins as enzymes which increased the seedling vigour index of bolder seeds that contain greater metabolites for resumption of embryonic growth during germination (Anitha *et al*., 2015).

In the last two decades, seed priming, being an effective seed invigoration method, has become a common seed treatment to increase the rate and uniformity of emergence and crop establishment. Seed priming is widely recommended pre sowing seed treatment, proven for its invigorative effect. Seed priming is a technique for enhancing the seed quality and seed storage in a wide range of crop species (Mc Donald, 2000). Seed priming is a pre-sowing strategy for improving seedling establishment by modulating pre-germination metabolic activity prior to radicle emergence and generally enhances germination rate and plant performance (Bradford, 1986)

Priming allows seed hydration to initiate the early events of germination, but prevention of emergence, followed by drying back to its initial moisture (McDonald, 2000; Ashraf and Foolad, 2005). There are reports that seed priming permits early DNA replication, increase RNA and Protein synthesis, enhances embryo growth, repairs deteriorated seed parts and reduces leakage of metabolites (McDonald, 2000).

The seed priming is an effective seed treatment to increase the rate, uniformity of emergence and crop establishment in most of the crops. Bio-priming is a seed treatmentwhich involves coating the seed with biological agents that integrates the biological and physiological aspects of enhancing of growth, disease control and increases yield. Excessive and continuous use of chemical fertilizers coupled with pesticides and fungicides have damaged the cultivation and productivity. Now a day the chemical fertilizer replaced by bio-fertilizer manufactured in India is solid carrier based and generally suffer from shorter shelf life, poor quality, high contamination and low field performance (Hegde *et al*., 1999).

Seed size is one of the important key factors for crop improvement. Due to various seed production environment and cultural practices. To eliminate non seed materials, other foreign seeds and low quality seeds of same species, grading act as an integral part of seed production and enhances the planting value. Studies pertaining to seed grading based on seed size in relation to seed quality characters are warranted as amount of food reserve in seed is the basic requirement for its future expression as germination and final establishment at field. In addition to obtain uniform seed size within a variety, size grading is inevitable. Jerlin *et al.* (2010) and Vadivelu and Ramakrishnan (1983) reported that larger seeds have higher seeding survival, growth

and establishment. The purpose of grading is to improve the homogeneity of the seed lot by removing seeds of the same species with low quality. During size grading, the small seeds are discarded which are believed to include empty, underdeveloped and low viguor seeds (Ambika *et al*., 2014).

With this context, studies to standardize seed production procedures and to find out the optimum sieve size for size grading of seeds needs to be addressed. In the view of above facts, the research entitled "Influence of nutrient management and seed bio-priming techniques on seed yield and quality in quinoa (*Chenopodium quinoa* Willd.)" was undertaken with following objectives.

1. To study nutrient management on seed yield and quality.

2. To evaluate the seed bio-priming techniques on seed yield and quality.

3. To standardize the grading sieves to upgrade the seed quality.

II REVIEW OF LITERATURE

The brief review of literature pertaining to nutrient management on growth and seed yield in quinoa and influence of seed bio priming on seed yield and quality in quinoa are presented in this chapter. Since the research work in quinoa on these aspects is scarce, the research works carried out on these aspects in other related crops are also included in this chapter. The same is presented under the following headings

2.1 Effect of nutrient levels on growth and seed yield in quinoa and its seed production

Nutrition is crucial for harnessing the actual genetic potential of cultivar and optimizes the quantities to be supplied to sustain the soil fertility and crop productivity. It brings economy and efficiency in fertilizer use and favourably affects the physical, chemical and biological environment of soil. Priming enables seed to germinate and emerge even under adverse agro-climatic conditions such as cold and wet or extreme heat. Uniform emergence helps optimize harvesting efficiency, which can increase yield potential.

2.1.1 Study the nutrient management in seed yield and quality

Chakraborty *et al*. (2002) revealed that raising the level of nitrogen from 0 to 80 kgha^{-1} increased the growth, yield attributes and NPK uptake by the crop. Higher nitrogen 80 kg ha^{-1} produced significantly and economically higher yield under rainfed red lateritic soil. Seed inoculation of *Azospirilium* gave an additive effect over FYM, nitrogen and phosphorus application alone and the effect of *Azospirilium* was found to be equivalent to 20 kg Nha^{-1} through urea. The combined application of *Azospirillum* and nitrogen gave better effect than *Azospirillum* with phosphorus. However, rock phosphate recorded on par effect on growth and yield with SSP. Highest dry matter (409.8 g), LAI (1.15 m^2), ear heads (120.5 m^2), length of finger (7.2 cm), NPK uptake (126.2 kg ha^{-1}), grain and straw yield (1320.7 and 2771.3 kg ha^{-1}, respectively) were obtained by *Azospirillum* + N 80 kg ha^{-1} followed by *Azospirillum* + N 60 kg ha^{-1} which also gave on par effect. Sole application of *Azospirillum* recorded 51.12 per cent higher grain yield than control.

Pradhan and Pandey (2004) depicted that increasing the nitrogen level from 40 kg ha^{-1} significantly increased the number of panicles per plant, panicle length, straw yield and seed yield. Application of 40 kg N ha^{-1} gave significantly higher seed yield of 4817 kg ha^{-1} which might be due to efficient utilization of nitrogen by plants that lead to accumulation of more photosynthetic thus resulting in more dry matter in finger millet.

Turgut *et al.* (2006) evaluated that seeding rates and nitrogen (N) fertilizer on proso millet seed yield, crude protein levels, and biomass yield under irrigated and dryland condition. Results indicated seeding rate did not affect seed yield significantly. Seed yield and protein content increased with increasing N doses although biomass did not significantly increase. Maximum grain yield (5905 kg ha^{-1}) was obtained in plots fertilized with 225 kg ha^{-1} N.

Channabasavanna *et al*. (2008) examined that influence of organic fertilizer on grain yield of maize. The result reveals that the application of poultry manure @ 1-ton ha^{-1} with 100 per cent RDF recorded the highest grain yield (6149 kg ha^{-1}), highest productivity (8341 kg ha^{-1}) and water use efficiency (17.38 %) compared to 75 percent RDF.

Jagjothi *et al.* (2008) revealed that band placement enriched FYM tha^{-1} + 100 % recommended N and K recorded significantly higher number of productivity tillers (176 $kgha^{-1}$), higher grain and straw yield (3269 and 5908 kg ha^{-1}, respectively) compare to control. The highest net returns (Rs. 13,446 ha^{-1}) and benefit cost ratio 2.69 were registered with band replacement of enriched FYM 2 t ha^{-1} +100 % RDF of N and K in direct sown finger millet under rainfed condition.

Apoorva *et al*. (2010) revealed that application of fertilizer 10 t ha^{-1} FYM + *Azatobacter* + PSB (*Phosphorus Solubilizing Bacteria*) recorded the highest plant height (123 cm), highest number of tillers per hill(4.6) at harvest,highest 1000 seed weight (4.12 g), seed yield and straw yield (3740.2 kg ha^{-1} and 9485 k ha^{-1}) compared to control (88.6 cm, 3.0, 2.93 g, 2649.2 kg $ha^{-1}$and 6893.4 kg ha^{-1}, respectively) in finger millet.

Waskin *et al.* (2012) evaluated the performance of maize under different rates of nitrogen and found that grain yield with 250 kg N ha^{-1} boosted significantly

increase by six per cent over the 150 kg N ha^{-1} and 200 kg N ha^{-1}, while stoved yield increase by eight and four per cent. Yield attributes like cob length and cob girth increased significantly with increase in nitrogen level from 150 to 250 kg N ha^{-1}. However, statistically non-significant increase in shelling percent (75.61 %) and test weight (21.47 g) was noticed due to application of 250 kg N ha^{-1} over the other control.

Prabudoss *et al.* (2013) examine the effect of integrated nutrient management (INM) on growth, yield and economics of transplanted kodo millet. Among the treatments, 125 per cent recommended dose of fertilizers (55:27.5:0 kg NPK ha^{-1}) + soil application of *Azospirillum* @ 2 kg ha^{-1} + vermicomposting @ 2 t ha^{-1} + foliar application of 1 percent poly feed at tillering and flowering recorded the highest yield attributes *viz.*, number of panicles $hill^{-1}$(154.46), number of grains $panicle^{-1}$(154.43), thousand grain weight (7.03 q) of transplanted kodo millet compare to control.

Iqbal and Afzal (2014) recited that soil application of nitrogen at 75 $kgha^{-1}$ improved all growth parameter 1000 seed weight (2.19 g) and grain yield (16.46 kg ha^{-1}) increased with increased N application over control was recorded in genotype CPJ2 in quinoa.

Anitha *et al*. (2015) evaluated the yield and quality aspects of fenugreek seed under different combinations of manures and fertilizers. Seed yield in the presence of 50 per cent inorganic fertilizers and 50 per centorganic manures along with bio-fertilizer inoculation recorded maximum seed yield (721.40 kg ha^{-1}) andnon-significant difference observed in the treatment combinations for germination percent and speed of germination compared to control fertilizer alone.

Claudir *et al*. (2015) emphasised that application of 90 kg N ha^{-1} significantly increased the plant height (72.5 cm), stem diameter (3.58 mm), panicle length (22.20 cm), grain yield (3001 kg ha^{-1}) and straw yield (4436 kg ha^{-1}) over no fertilizer (55.5 cm, 3.32 mm, 12.5 cm, 2707 kg ha^{-1} and 3245 kg ha^{-1} respectively) in proso millet.

Bhomte *et al*. (2016) found that high fertilizer dose (60:30:0 kg ha^{-1} NPK) gave more plant height (80.81 cm), more number of tillers $plant^{-1}$ (9.16) and high grain yield (783 kg ha^{-1}) in little millet as compared to lower doses of fertilizer

(20:10:0 kg ha^{-1} NPK) which gave less plant height (69.09 cm), less number of tillers $plant^{-1}$ (6.99) and less grain yield (675 kg ha^{-1}).

Chaudhari *et al*. (2016) revealed that application of 50 % RDN through chemical fertilizers + 25 per cent N through vermicompost + 25 per cent N through neem cake to summer pearl millet crop resulted in significantly higher seed yield (2613 kg ha^{-1}) followed by the treatments with application of 50 % RDN through chemical fertilizers + 25 per cent N through bio compost + 25 per cent N through neem cake and 50 per cent N through chemical fertilizers + 25 per cent N through vermicompost + 25 per cent N through castor.

Dwivedi *et al*. (2016) carried out to improve kodo yield through different inputs and their integration to reduce the input cost. Inorganic fertilizers (100 per cent NPK) gave promising grain yield (1435 kg ha^{-1}) over control (620 kg ha^{-1}) but it is realized that they are beyond the purchasing power of these resource poor farmers. *Azotobacter* + PSB was better in grain yield (695 kg ha^{-1}) as compared to *Azospirillum* + PSB (665 kg ha^{-1}). While FYM alone gave seed yield (815 kg ha^{-1}). Integration of the entire inputs 50per cent NP + 100per cent K+ *Azotobacter* + PSB+ FYM proved that best and increased the kodo yield (1585 kg ha^{-1}) significantly.

Jayashri (2016) concluded that seed priming on germination and seedling growth of maize and treated the seeds with bio agents, chemical and water for 12 h and 24 h. Increase in N level from control to 150 % of RDN enhanced growth and yield parameters significantly. Application of 180 kg N ha^{-1} (150 % RDN) recorded the maximum grain yield (44.68 q ha^{-1}) and stover yield (85.43 q ha^{-1}) which boosted significantly by 30.30 and 24.07 % respectively over the control.

Jyothi *et al*. (2016) discussed that application of 50 kg N ha^{-1} markedly improved the growth plant height (105.6 cm), number of tillers (9 m^2), dry matter production (4069 kg ha^{-1}), seed yield (1398 kg ha^{-1}) and straw yield (2547 kg ha^{-1}). lowest with no nitrogen application. The improvement in yield with enhanced nitrogen application might be attributed to better availability and uptake of nutrients, which in turn lead to efficient metabolism.

Pallavi *et al*. (2016) evaluated finger millet grown under three years old *Meliaazedarach* in red sandy loam soil with different management *viz*., application of

FYM @ 10 t ha^{-1} , 100 % RDF (40:20:20 NPK kg ha^{-1}) alone and in conjunction with 75 % RDN with 25 % N through FYM, vermicomposting, poultry manure; also with bio fertilizers @ 5 kg ha^{-1}*Azospirillum* and PSB along with finger millet alone as sole cropping with 100 per cent RDF.The highest grain yield (2681 kg ha^{-1}) and straw yield (5063 kg ha^{-1}) resulted with sole crop on par with 75 % RDN + 25 % N poultry manure (2405 and 4733 kg ha^{-1}, respectively) and 100 % RDF (2393 and 4745 kg ha^{-1}, respectively).

Thumar *et al*. (2016) revealed that application of FYM @ 2.5 t ha^{-1} along with recommended dose of fertilizer (120 kg N + 60 kg P_2O_5 ha^{-1}) and seed inoculation with *Azotobacter* and *phosphorus solubilizing bacteria* (PSB) resulted significantly highest plant height of (174.28 cm) at harvest, number of total tillers $plant^{-1}$(4.93), number of effective tillers $plant^{-1}$(4.13), ear head length (24.99) cm, ear head girth (3.20 cm), test weight (9.76 g), grain yield (3631 kg ha^{-1}) and fodder yield (7492 kg ha^{-1}) over the control in pearl millet.

Umesh (2016) observed that significant increase in yield (3153 kg ha^{-1}) in finger millet with 100 percent RDF + compost @ 5 t ha^{-1} over 100 percent RDF (2772 kg ha^{-1}) and 50 percent RDF + compost @ 5 t ha^{-1}).

Nigade *et al*. (2017) investigated the effect of different organic and inorganic sources of nutrients on crop yield of finger millet and soil properties. The results revealed that, on Entisols of sub-montane zone of Maharashtra, application of recommended dose of chemical fertilizers (60:30 NP kg ha^{-1}) recorded the highest seed and biological yield (2.92 and 4.07 t ha^{-1}, respectively).

Sandhy *et al*. (2017) indicated that significantly higher grain and straw yield of finger millet were recorded in the treatment with 150 percent of RDF + $ZnSO_4$ @ 0.5 per cent foliar spray + $FeSO_4$ (0.2 %) foliar spray (78.1 q ha^{-1} and 33.7 q ha^{-1}, respectively).

Krishnaprabu (2018) found that plant height (218.58) and seed yield (7496 kg ha^{-1}) had registered highest value under application of 75 % RDF + bio compost @ 4 t ha^{-1}+ *Azotobacter* + *Azospirillum* compare to control (RDF alone: 114.68 cm and 3628 kg ha^{-1}, respectively).

Monisha *et al*. (2019) observed that combined use of organic and inorganic sources along with bio-fertilizers were significantly influenced the growth parameters and grain yield in red soil. Application of 50 per cent RDF + 25 per cent neem cake N Based + 25 per cent bio-fertilizer had superior effect on plant height (132.3cm), number of tillers plant^{-1} (7.2), panicle length (17.8 cm), test weight (2.73 g), grain yield (2385 kg ha^{-1}) and straw yield (4293 kg ha^{-1}) of foxtail millet.

2.2 Seed bio-priming techniques on seed yield and quality

2.2.1 Effect of seed bio-priming on growth seed yield and seed production in quinoa

Niranjanraj *et al*. (2004) revealed that pearl millet primed with five isolates of *Pseudomonas fluorescens* promoted the vegetative and reproductive growth. The isolate UOM SAR 14 recorded the greatest increase in growth parameters like plant height(126.2cm), leaf area (41.00 cm^2) and reproductive parameters such as panicle length (12.3 cm) and girth of ear head (5.9 cm) and 1000 seed weight (6.8 g) compare tounprimed seeds.

Kumawat *et al*. (2010) revealed that *Trichoderma harzianum,* and *Trichoderma viride* were effective in minimizing the mycelial growth of *Drechslera oryzae* from 17.86 to 39.64 per cent. The maximum inhibition was recorded in *Trichoderma harzianum*. Seed dressing with spores suspension of *Trichoderma* stimulated the growth of plants, increased shoot length and root length over control-I (*D. oryzae*) and control-II (Healthy).

Priya *et al*. (2011) studied the effect of seed priming practices on growth, yield and economics of maize and releaved that bio-priming with *Pseudomonas, Azospirullum, Trichoderma* and vesicular *arbescular mychorhiza* and in the combination of all priming methods were found to be beneficial than farmer's practices. Increase maize yield was to the tune of 13.63 to 14.41 per cent over the farmers practise (unprimed seeds).

Prathibha and Siddalingeshwara (2011) investigated that seed primed with *P. fluorescens and B. Subtili spromotes Rhizobacteria* in sorghum CSH-14 variety and *P. Fluorescens* recorded highest (84 %) seed germination compares to control (78 %).

Nagaraju *et al*. (2012) investigted that sunflower seeds primed with three rhizosphere fungal isolates *viz.*, PGPFYCM2, PGPFYCM-8 and PGPFYCM-14 of *Trichoderma harzianum*, PGPFYCM14 had highest (91 %) germination followed by PGPFYCM2 (90.25 %) and PGPFYCM-8 (88.5 %) over un-primed seeds (86.25 %)

Pratibha *et al*. (2012) primed wheat seeds with *Trichoderma harzianum* 4 g kg^{-1} and @ 4ml L^{-1} along with soil treatment with a mixture of farmyard manure and formulation @ 50:1 before sowing. A significant increase in yield (from 36.25 to 46.73 q ha^{-1}) was observed in primed seeds.

Punithavathi (2012) concluded that seed priming with Azophos 1.0 per cent, *Pseudomonas fluorescens* 1.0 per cent could be recommended as suitable priming treatments for enhancing germination (91 %) and vigour index (3101) of Rice.

Umesha *et al*. (2014) revealed that effect of organics and bio fertilizers on growth and yield of maize recommended dose of NPK + *Azotobacter chroococcum* + *Bacillus megaterium* + *Pseudomonas fluorescens* + enriched compost has showed highest plant height at 30, 60, 90 DAS and at harvest (31.70, 180.93, 186.07 and 188.13 cm, respectively). Yield parameters like weight of cob (207.63 g), seed yield per plant (158.93 g), seed yield per ha (54.53 q) and test weight of seeds (33.10 g) was also found highest in the same treatment.

Famina and Shafie (2015) evaluated the effect of bio priming under drought stress on yield components of maize and found that application of *Pseudomonas fluoresces* had the highest number of cobs per plant (1.7), highest cob length (26 cm), more number of row per cob (16), highest number of grain per row (46) and highest grain yield (255 gm^{-2}).

Srivastava *et al*. (2015) the kodo and barnyard millets seeds primed with *Pseudomonas fluorescens* 20 % for 6 h registered higher speed of germination (11.23 and 20.66, respectively) and germination (86.00 % and 88.00 %, respectively) with an increase of 6.9 and 7.9 %, respectively was noticed for germination due to *Pseudomonas fluorescens* priming over nonprimed seeds.

Sridevi and Manonmani (2016) examine the effect of seed priming on physiological performance of kodo and barn yard millets and they releaved that

primed seeds with *Pseudomonas fluorescens* @ 20 per cent for 6hr showed early germination, higher germination, shoot and root length, dry matter production, vigour index and seed metabolic efficiency than seeds primed with KH_2PO_4 @ 2 per cent, hydroprimed and non-primed seeds.

Madhukeshwara and Ashok (2017) revealed that seed bio-priming with *Azospirillum brasilense* (20 %) recorded significantly higher field emergence (96.30 %), plant height at harvest (210 cm), minimum number of days to 50 per cent tasseling and silking (53.00 and 57.33, respectively) and yield (68.28 q ha^{-1}) compare to non-primed seeds. The study indicated that seed bio-priming with *Azospirillum brasilense* (20 %) significantly enhanced the crop growth and also increased the yield by 22.8 per cent which was on par with *Pseudomonas striata* (20 %).

Irum Mukhtar (2008) evaluated the three *Trichoderma* species for their potential effect on okra seed germination and results revealed that all the tested *trichoderma* sps. were found effective in enhancing the germination per cent. However, among the three species, *Trichoderma harzianum* (85 %) exhibited significant enhancement of germination in okra seeds compared to *T. Viridi* (78 %) and *T. Koningii* (76 %).

Pramod Sharma *et al*. (2018) revealed that effect of seed bio-priming with microbial inoculants on plant growth and yield contributing characters in soybean (*Glycine max* (L.) Merril) Among all the treatments, highest field emergence (88.47 %) and minimum days to 50 per centflowering (40.75 days) was recorded in Psf-173 inoculant while maximum plant height (30.34 cm) was measured in Th-14 inoculant. However, PSB bio-primed seed improved seed yield and other contributing characters.

Balaji and Sathitya (2019) noticed that seeds bio primed with *Pseudomonas fluorescens* 20 % (liquid formulation) for 6 h produced higher speed of emergence (57.2), germination (94.00 %), seedling length (20.1 cm), dry matter production (45.1 mg) and vigour index (1899) and speed of emergence (80.10), germination per cent (86.00 %), seedling length (20.5 cm), dry matter production (21.5 mg) and vigour index (1776) when compared to un-primed seed.

2.3 Standardise the grading sieves for upgrade the seed quality.

Vadivelu and Ramakrishnan (1983) reported that the large size (retained on 6 x 6 mm screen) and medium size seeds (retained on 5 x 5 mm screen) showed significantly higher seed recovery, 1000 seed weight, germination, seedling dry matter, vigour index and field emergence compared to small size (4 x 4 mm) screen and ungraded seeds in Bengal gram.

Shashidhar *et al*. (1987) reported in cowpea that the lowest germination (90.00%) recorded from the seeds graded on 2.78 mm sieve, while the seeds sieved on 3.98 mm sieve showed highest germination (94.00 %) and seedling dry weightindicating increase in seed size significantly in seed quality.

Bhor *et al*. (1998) recorded non-significant differences in germination and vigour index due to different seed size raded between 7.50 and 8.00 mm sieves. The seedlings produced from bolder seeds (retained above 8.00 mm sieve) showed higher fresh and dry weight compared to the smaller (passed through 7.50 mm sieve) and ungraded seeds in bengal gram.

Sivasubramaniam (2000) examined that bimodal grading kolingi (*Tephrosia purpurea*) seeds using round holed sieve of 7/64", 6/64"and 5/64" and seeds retained in each sieves were again graded using slotted sieves of 1.8mm, 1.6mm and 1.4 mm. Result showed that highest seed recovery (86 %), test weight (1.385 g) and germination (50 %) was recorded in seeds retained by 7/64" were further graded using 1.8mm.

Maurya *et al*. (2002) reported that among the three different grades *viz.,* large (5.5mm), medium (4.5-5.5 mm) and small (4.5 mm) of soybean seeds, large and medium sized seeds recorded highest values of field emergence, plant stand, seed yield and germination index while the small sized seeds indicated least response with respect to all variables.

Balamurugan *et al*. (2004) revealed safflower (k1) seeds retained in 11/64 round perforated metal sieve recorded higher germination (94.00%), vigour index (1362) and productivity (800 kg ha^{-1}) compared to other 18/64", 12/64" and 10/64" sieves.

Sivakumar (2005) examined that size grading in ambrette seeds with BSS 8X8 wire mesh sieve and registered the maximum recovery (89.80 %) of good quality seeds with higher germination of 82 percent with higher protein, starch and oil contents and seedling vigour.

Jerlin *et al*. (2010) concluded that optimum sieve size for size grading of seeds of olitorius jute *cv*. JRO 524 and JRO 8432. Pre cleaned seeds of both the cultivars were size graded using BSS 12x12, BSS 14x14 and 16x16 wire mesh sieves. The jute *cv*. JRO 524 seeds graded with BSS 16x16 recorded high seed recovery (59.45 %) than other sieves.

Manikandan and Srimathi (2014) examined that graded seeds retained in BSS22 x22 sieve recorded 87 per cent recovery with higher germination (96 %) and vigour index (883) in amaranthas (*Amaranthus hypochondriacus* L.) *cv*. Suvarna compare to other sieves.

Kumar *et al*. (2014) graded green gram varieties *viz.* MH-421 and SML-668 were graded using various sieves on seed cleaner cum grader in order to find out the optimum sieve size for maximum seed recovery and quality seed. The results revealed that 2.4 mm sieve size was found effective and economical for grading MH421 for maximum seed recovery (72.10 %) with better seed germination (76.00 %), which meets IMSCS while the sieve of 3.00 mm size was found effective and economical for grading SML-668 for maximum seed recovery (75.20 %) and better seed germination (80.00 %).

Somasekhara *et al*. (2015) subjected hybrid sunflower, KBSH-1 seeds for large scale processing using different sieve sizes (2.4, 2.6, 2.8, 3.0 and 3.2 mm) and the results revealed that, the seed recovery decreased significantly with increase in sieve size from 2.4 mm (87.50 %) to 3.2 mm (31.10 %). The presently prescribed sieve size of 2.8 mm recorded a seed recovery of 63.30 per cent as compared to 84.90 per cent with 2.6 mm sieve size. The seed quality parameters like 100 seed weight, husk content and seedling dry matter and vigour index increased significantly with increase in sieve size from 2.4 to 3.2 mm.

Ganiger *et al*. (2016) optimized sieve size for size grading, maximum recovery of seeds and seed quality values in green gram cv. BGS-9 using oblong/slotted shape

sieve of 2.4, 2.6, 2.8, 3.0 and 3.2 mm size. Based on two years' data, the results revealed that the 2.4mm sieve recorded high seed recovery (94.81 %) than other sieves with seed quality parameters like germination percentage (87.74 %), 100 seed weight (4.76 g), pure live seed (87.97 %) and physical purity (98.53 %).

Ganiger *et al*. (2019) evaluated that seed size and seed quality in soybean *cv*. DSB21 seeds using 3.75mm, 4.00mm, 4.25mm, 4.5mm and 4.75mm of slotted perforated metal sieves and revealed that larger sized seeds are obtained from 4.5mm and 4.75mm sieves with maximum germination and seedling vigour. The graded seeds obtained from the sieve 3.75 mm recorded the highestrecovery (83.90 %), physical purity (98.49 %), germination (75.00 %), 100 seed weight (15.685 g), pure live seed (74.11 %) and vigour index (2826).

Suruthi *et al*. (2019) optimized sieve size for size grading of seeds of barnyard millet (*Echinochloa frumentacea* L.). The effect of seed size on physiological parameters were evaluated using BSS 10×10, BSS12×12 and BSS 14×14 wire mesh sieves along with control. The barnyard millet seeds graded with BSS 12×12 recorded higher seed recovery (76.67 %) and germination (92.00 %), 1000 seed weight (3.9g), root length (14.1cm), shoot length (8.45 cm), dry matter production (0.027 g/10 seedlings) and vigour index (1983) compare to other sieves and ungraded seeds.

III MATERIAL AND METHODS

Field and laboratory experiments were carried out in quinoa (*Chenopodium quinoa* Willd.) during *Rabi*, 2019 at Indian Institute of Seed Science, MAU Regional Station, GKVK, Department of Seed Science and Technology, College of Agriculture, UAS, GKVK, Bengaluru. The details of all the materials used and methodology that has been followed during the course of investigation are furnished in this chapter.

3.1 General description

3.1.1 Location of the experimental site

Quinoa *cv*. EC507740 was raisedduring *Rabi*, 2019 at Indian Institute of Seed Science, MAU Regional Station, GKVK, Bengaluru that is situated between 12° 15' North latitude and 77° 35' East longitudes, at 930 m altitude above Mean Sea Level (MSL).

3.1.2 Soil status

The nature of experimental plot soil is red laterite. Before the initiation of experiment, soil sample from 0 to 30 cm depth were collected from each plot in different treatments. Soil sample was air dried, powdered and allowed to pass through twomm sieve. The soil sample was analyzed for initial fertility status in field. The detailed fertility level of major, micronutrient and pH are presented in the Appendix-I.

3.1.3 Climatic conditions

GKVK has semi-arid climate. The normal weather data and the actual weather data during the year of experimentation (September 2019 to December 2019) with respect to total rainfall, relative humidity and temperature (maximum and minimum), during the crop growth period were recorded at the agro meteorological unit GKVK and are presented in the Appendix - II.

3.2 Experimental details

3.2.1 Source of seed

The freshly harvested quality seeds of quinoa variety, EC 507740 collected from ICAR - Indian Institute of Seed Science MAU, Regional Station, GKVK, Bengaluru were used for sowing.

3.2.2 Description of the variety (EC 507740)

EC 507740 is the exotic variety of quinoa crop. It matures in about 85-95 days with an average yield of 15-30 q ha^{-1}, it grows to about 2.0 meters tall and can be grown in all types of climatic conditions and 45 x 15 cm is taken as recommended spacing and 60:40:20 NPK Kg ha^{-1} is recommended nutrient application.

Experiment I: To study the effect of nutrient management and seed bio-priming on seed yield and quality

The experiment was laid out with 12 treatments in three replication using Factorial Randomized Complete Block Design (Fig 3.1)

Treatment details:

Location	: ICAR-IISS, RS GKVK, Bengaluru
Crop	: Quinoa
Variety	: EC 507740
Season	: Rabi, 2019
Design	: FRCBD
Treatments	: 12
Replication	: 3
Seed rate (kg ha^{-1})	: 10
Net Plot size	: 1.8 × 0.8 = 5.04
Gross plot size	: 2.0 x 3.0 m = 6.00
Spacing	: 45 ×15 cm
Date of sowing	: 18-11-2019
Date of harvest	: 18-02-2020

I. Nutrient levels:

N_1 : RDF 60:40:20 NPK kg ha^{-1}

N_2 : 80: 50: 50 NPK kg ha^{-1}+2 % $FeSO_4$ spray at flowering

N_3 : 80: 50: 50 NPK kg ha^{-1}+ 2 % DAP spray at pre-flowering

N_4 : 25 kg neem cake ha^{-1} + 1250 kg vermicompostha^{-1} + 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1} + 10 kg *Azospirillum* ha^{-1}

II. Seed bio priming

P_1 : Control (Unprimed)

P_2 : Seed priming with *Trichoderma harzianum* (1.5 %) 6 hours

P_3 : Seed priming with 20 % liquid *Pseudomonas fluorescens* (6 hours)

Total treatments: Nutrient levels (4) x Seed bio-priming treatments (3)

TREATMENTS	TREATMENT DETAILS
N_1P_1	60:40:20 NPK kg ha^{-1} with unprimed/Control seed
N_1P_2	60:40:20 NPK kg ha^{-1} with Seed priming with *Trichoderma harzianum* (1.5 %)
N_1P_3	60:40:20 NPK kg ha^{-1} with Seed priming with 20 % liquid *Pseudomonas fluorescens*
N_2P_1	80: 50: 50 NPK kg ha^{-1} + 2 % $FeSO_4$ spray at flowering with unprimed/Control seed
N_2P_2	80:50:50 NPK kg ha^{-1} +2 % $FeSO_4$ spray at flowering with Seed priming with *Trichoderma harzianum* (1.5 %)
N_2P_3	80:50:50 NPK kg ha^{-1} +2 % $FeSO_4$ spray at flowering with Seed priming with 20 % liquid *Pseudomonas fluorescens*
N_3P_1	80: 50: 50 NPK kg ha^{-1} + 2 % DAP spray at pre-flowering with unprimed/Control seed
N_3P_2	80: 50: 50 NPK kg ha^{-1} + 2 % DAP spray at pre-flowering with Seed priming with *Trichoderma harzianum* (1.5 %)
N_3P_3	80:50:50 NPK kg ha^{-1} + 2 % DAP spray at pre-floweringwith Seed priming with 20 % liquid *Pseudomonas fluorescens*
N_4P_1	125 kg neem cake ha^{-1} + 1250 kg vermicompostha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+ 10 kg *Azospirillum* ha^{-1} with unprimed/Control seed
N_4P_2	125 kg neem cake ha^{-1} + 1250 kg vermicompostha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+ 10 kg *Azospirillum* ha^{-1} with Seed priming with *Trichoderma harzianum*(1.5 %)
N_4P_3	125 kg neem cake ha^{-1} + 1250 kg vermicompostha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+ 10 kg *Azospirillum* ha^{-1} with Seed priming with 20 % liquid *Pseudomonas fluorescens*

3.2.3 Land preparation

Land was ploughed with tractor drawn disc plough. Cultivator was passed once. The soil was softened with the rotavater to break down the clods and prepared a fine bed with good soil tilth. After the land preparation, layout of experimental plot was prepared and the land was divided into plots of required size of (2.0 x 3.0= 6.00 m^2) and leveled.

3.2.4 Seed bio-priming

The freshly harvested quality seeds of quinoa variety, EC 507740 collected from ICAR - Indian Institute of Seed Science MAU, Regional Station, GKVK, Bengaluru and seeds are treated with 20 % liquid *pseudomonas flourescens* and *Trichoderma harzianum* (1.5 %) for 6 hours and kept 12 hours for shade drying and used for sowing.

3.2.5 Seeds and sowing

The quality seeds were sown to a depth of about 2.0 cm, with respective spacing treatment on 18th November 2019.

3.2.6 Thinning and gap filling

Thinning and gap filling done after ten days of sowing (28th November, 2019), thinning and gap filling were done manually to maintain optimum plant population.

3.2.7 Water management

Protective irrigation was given to the crop as and when required at 10-15 days interval. Two irrigations were given at the panicle stage to boost the yield at 30-35 after sowing followed by 40 - 45 days after sowing.

3.2.8 Weeding

Two hand wedding's (first weeding on 30th November, 2019 and second weeding on 10th December, 2019) was done with the help of labour, two inter cultivations were done to give aeration and to maintain weed free condition of plot.

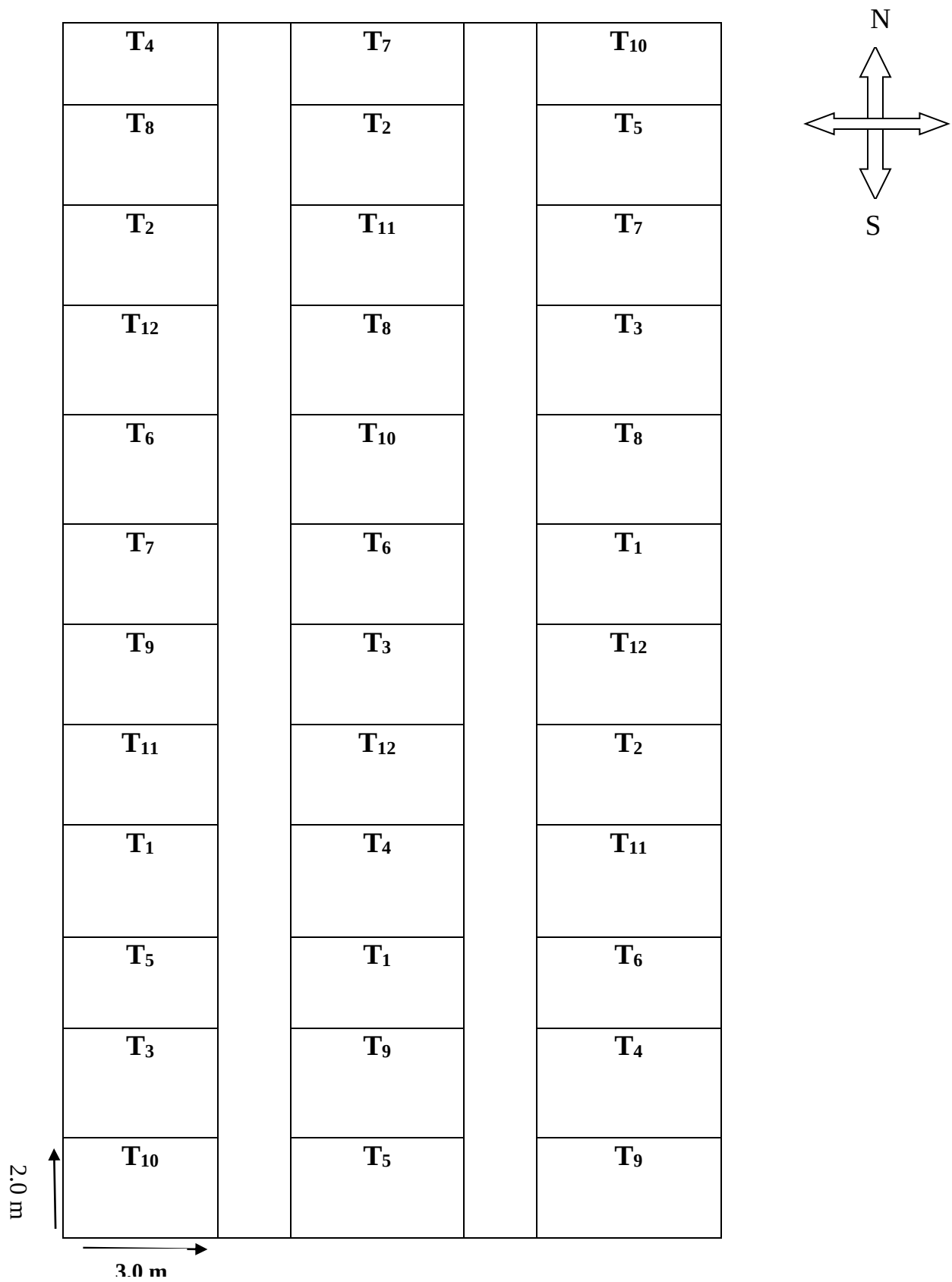

Fig. 3.1: Design and layout of experimental lot

Plate 1: General view of experimental plot

3.2.9 Spraying of nutrients

Two per cent ferrous sulphate and two per cent of 2 per cent DAP were spayed at flowering and pre-flowering stages respectively.

3.2.10 Harvesting and threshing

The crop was ready for harvest at 87–93 DAS (between 18th November 2019and 18th February 2020) with respect to maturity of treatments, which was indicated by pink colored panicles followed by brown colored panicles. The harvested panicles were sun driedfor days on threshing floor. Threshing was done by beating the panicles with the sticks manually.

3.2.11 Cleaning and grading

The threshed seeds were further cleaned by winnowing. The seeds obtained were tried to clean with different sieves and it was observed that 1.4 mm (R) sieve was suitable for grading the quinoa seed. The seeds were graded by using 1.4 mm (R) sieve size and net plot seed yield was recorded after thorough drying and expressed in kilograms.

3.3 Observation recorded

3.3.1 Growth and yield parameters

Five plants in each treatment within replicationwere selected randomly and tagged with a label for recording various growth and yield parameters.

3.3.1.1 Field emergence (%)

Field emergence was recordedby counting the number of seeds germinated and emerged in the field on 10th day after sowing. The field emergence was calculated by using formula suggested by the Saha and Basu (1981).

$$\text{Field emergence (\%)} = \frac{\text{Number of seedlings emerged}}{\text{Total number of seeds sown}} \text{X100}$$

3.3.1.2 Plant height (cm)

The plant height was measured from the base of the plant at ground level to the growing tip of the plant (base of the top leaf) at 30, 60 DAS and at harvest stage. After emergence of the panicle, the height was taken up to the base of the panicle on the main shoot. The average plant height was computedout and expressed in centimeters.

3.3.1.3 Total number of panicles plant^{-1}

From randomly selected five plants, total number of panicles plant^{-1}was calculated at harvesting stage. Data was pooled and average total number of panicles was determined.

3.3.1.4 Total number of branches

From randomly selected five plants, total number of branches was counted at harvest stage. Data was pooled and average total number of branches was calculated.

3.3.1.5 Days taken to 50 per cent flowering

Daily counts were made in each treatment plot to know the days taken to 50 per cent. The date on which 50 per cent of the total plants were flowered in each plot was recorded. The number of days taken to 50 per cent flowering was computed from the date of sowing and mean was expressed as whole number.

3.3.1.6 Days taken to maturity

Daily counts were made in each plot to know the days taken to maturity. The date on which 100 per cent of total plants were matured in each plot was recorded. The number of days taken to 100 per cent maturity was computed from the date of sowing and mean was expressed as whole number.

Plate 2: General view of experimental plot during grain filling stage

3.3.2 Yield parameters

3.3.2.1 Panicle length of main stem (cm)

Panicle of main stem from the randomly selected five plants in each treatment from all replication was harvested and length is measured from base to tip of the panicle and expressed in centimeter.

3.3.2.2 Panicle dry weight (main + secondary) per plant (g)

From randomly selected five plants in each treatment, panicles were harvested separately, shade dried for 4-5 days, and weight was recorded. Average weight of each plant was computed and expressed in grams.

3.3.2.3 Seed yield per plant (g)

Panicles from randomly selected five plants in each treatment were threshed, shade dried (3 days) and seed yield were weighed, average weight is computed and expressed in grams.

3.3.2.4 Seed yield per plot (g)

Panicles from each net plot were threshed, shade dried and seed yield weight was recorded each treatment from all the replications was averaged and expressed in grams.

3.3.2.5 1000 seed weight (g)

Seed sampleswere drawn from each treatment and thousand seeds were counted in four replications and weighed. The mean weight of the sample was recorded as test weight and expressed in grams (Anon., 1996).

3.3.2.6 Seed yield per hectare (kg ha^{-1})

The panicles from each net plot were threshed, shade dried and seed yield was recorded. Each treatment in three replications was averaged and calculated for one hectare.

3.3.3 Seed quality parameters

3.3.3.1 Seed germination (%)

The germination test was conducted in the laboratory by using between paper method as per ISTA rules (Anon., 1996). A total of 400 seeds were randomly selected from each treatment and grouped into four replications of 100 seeds each. Seeds were placed equidistantly on moist germination paper. The paper towels were rolled along with polythene cover and banded with rubber band. The rolled towels were incubated in germination chamber maintained at 25± 1ºC temperature and 90± 2 per cent relative humidity (RH). The first count and final count of normal germinated seedlings were taken on 8^{th} and 10^{th} day, respectively. The percentage of germination was expressed based on normal seedlings present in the tested sample.

The following traits such as normal seedling, abnormal seedling, fresh un-germinated seeds, hard seeds, mean seedling length, root length, shoot length, mean seedling dry weight were measured based on the seeds incubated for germination test on 10^{th} day after incubation.

$$\text{Seed germination (\%)} = \frac{Number\ of\ seeds\ germinqted}{Total\ number\ of\ seeds\ put\ for\ germination} X\ 100$$

3.3.3.2 Mean root length (cm)

Ten normal seedlings were selected randomly from each treatment. The root length was measured from the tip of primary root to the base of hypocotyl and mean root length was expressed in centimeter (Anon., 1996).

3.3.3.3 Mean shoot length (cm)

Ten normal seedlings were selected randomly from each treatment. The shoot length was measured from the base of primary leaf to the base of hypocotyl and it was expressed in centimeter (Anon., 1996).

3.3.3.4 Mean seedling length (cm)

Ten normal seedlings were randomly selected from each treatment and replication and then carefully separated from the wet paper towel of the germination

Plate 3:General view of experimental plot during maturity stage

test. The total length of the seedling was measured from tip of primary root to tip of primary leaf by using a measuring scale. The mean of ten seedlings from each treatment in each replication was calculated and is expressed in centimeters (Anon., 1996).

3.3.3.5 Mean seedling dry weight (mg)

The ten normal seedlings were selected randomly from the germinated seedlings for measuring the seedling length were placed in the butter paper bag by removing the cotyledon and dried in a hot air oven, maintained at 80±1˚C temperature for 48 hours. Then the seedlings, which were removed, are allowed to cool indesiccators for 30 minutes and weighed in an electric balance. The weight of the dried samples was recorded and it is expressed in milligram (Anon., 1996).

3.3.3.6 Seedling vigor Index-I

Seeds kept for germination test by using between paper method. The seedlings that germinated were evaluated on 8^{nd} and 10^{th} day as first and final counts respectively and the percentage of germination was expressed based on the normal seedlings present in the test and then ten normal and healthy seedlings from each replication were selected randomly on 10^{th} day and seedling length (shoot and root) was measured in centimeters.

The seedling vigor index - I was calculated as per the formula suggested by Abdul-Baki and Anderson (1973), by multiplying standard germination percentage with mean seedling length (cm) and expressed in whole number for each treatment.

SVI - I = Seed germination (%) x Mean seedling length (cm)

3.3.3.7 Seedling vigor index - II

Subjected seeds for laboratory germination test by following between paper method, the germinated seedlings were then evaluated on $8^{th}$and 10^{th} day as first and final count, respectively and the percentage of germination was expressed based on the normal seedlings obtained in the test. Then ten normal and healthy seedlings from each replication were selected randomly on 10^{th} day and seedling length (shoot and root) was measured in centimeters and its mean is measured and then those seedling

were dried in hot air oven maintained at 80 ± 10^{0}C for 48 hours and cooled in the desiccator. The mean seedling dry weight was recorded and expressed in milligrams.

Seedling vigour index-II was recorded by multiplying the standard germination percentage and seedling dry weight. It was computed by adopting the formula as suggested by Abdul-Baki and Anderson (1973) and expressed in whole number.

SVI II = Seed germination (%) x Mean seedling dry weight (mg)

3.3.3.8 Estimation of total dehydrogenase activity (A_{480} nm)

A total of 30 seeds were randomly selected from seeds (imbibed) incubated for EC from each treatment and grouped into three replications of 10 seeds each. Seeds were carefully pierced using needle without damaging the embryo and were soaked in 2 ml of 0.5 per cent tetrazolium solution in a test tube and incubated at 30 ± 1˚ C for a period of 24 hours then washed thoroughly with distilled water, the red colored formazan from stained embryos was diluted by soaking in 5 ml of 2-methoxyethanol (methyl cellulose) for 24 hours in an airtight screw capped vials. The extract will be decanted and the color intensity will be measured with the help of spectrophotometer (Model-Systronics UV-VIS spectrophotometer 117) OD value at 480 nm. The dehydrogenase activity was expressed in terms of optical density at A480 nm (Perl *et al*., 1978).

3.3.3.9 Electrical conductivity of seed leachate (dS cm^{-1})

Five grams of seeds from two replications were taken randomly from each treatment in a beaker. The collected seeds were soaked in 25 ml of distilled water for 24 hour at 25 ± 10° C. The steeped water from soaked seeds was collected and the electrical conductivity (EC) of seed leachate was measured in digital conductivity meter (Model: Systronic conductivity meter 306). After subtracting the EC of the distilled water from the value obtained from the seed leachate, the actual EC due to electrolytewas measured and expressed in dS cm^{-1} (Anon., 1996).

3.4 Experiment II: To standardize the grading sieves to upgrade the seed quality

The experiment was laid out with four treatments in three replications using completely randomized design.

Location	:	Department of Seed Science and Technology, GKVK
Crop	:	Quinoa
Variety	:	EC 507740
Design	:	CRD
Treatments	:	4
Replications	:	3

Treatments details: Sieve sizes

S_1: 1.2 mm (R)

S_2: 1.3mm (R)

S_3: 1.4 mm (R)

S_4: 1.6 mm (R)

3.4.1 Observation recorded:

3.4.1.1 Seed recovery (%)

The harvested seed from net plot were processed using recommended sieve size in (mm). The portion of sample that retained over the bottom sieve was considered as good seed. The seed recovery percentage was worked out of using this formula.

$$\text{Seed recovery (\%)} = \frac{Weight\ of\ seed\ retained\ on\ the\ sieve\ (g)}{Total\ weight\ of\ seed\ taking\ before\ the\ sieve\ grading\ (g)} X100$$

3.4.1.2 Seed quality parameters

As per procedures explained under 3.3.3.1 – 3.3.3.7 headings were followed to analyze the quality of graded seed.

3.5 Statistical analysis

Thestatistical analysis and interpretation of the experiment data was done by using Fisher's method of Analysis of Variance technique as outlined by Gomez and Gomez (1984). The level of significance used in 'F' and 'T' tests was at P=0.05 and critical difference values were calculated whenever 'F' test was significant.

VI RESULTS AND DISCUSSION

Results and discussion of present experiment entitled “Influence of nutrient management and seed bio-priming on seed yield and quality in Quinoa (*Chenopodium quinoa* Willd.)” conducted during Rabi 2019-20 at IISSc, Regional Station, MAU, UAS, GKVK, Bengaluru are as follows.

4.1 Growth parameters as influenced by nutrient levels and seed bio priming.

4.1.1 Field emergence (%)

The data on field emergence as influenced by different nutrient levels and seed bio priming and their interaction are presented in the table 4.1

The field emergence showed significant difference with respect to nutrient levels. the highest field emergence (88.44 %) was observed in (N_3) 80:50:50 NPK kg ha^{-1} + 2 % DAP spray followed by 80:50:50 NPK kg ha^{-1}+ $FeSO_4$ spray (N_2:87.00 %) and lowest field emergence was recorded in 125 kg neem cake ha^{-1} + 1250 kg vermicompost ha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+ 10 kg *Azospirillum* ha^{-1} (N_4:84.89 %).

Non-significant difference for field emergence due to difference of seed bio priming. However, the highest field emergence was recorded in seed priming with *Pseudomonas fluorescens* (P_3:87.4 %) and lowest field emergence was showed in control (P_1:85.50 %).

Non-significant difference noticed for field emergence. However, in the interaction of nutrients and seed bio priming, the maximum field emergence was recorded in N_3P_3 (91.00 %), while the minimum field emergence was recorded in N_1P_1 (81.00 %). Primed seed might have showed higher field emergence due to the production of microbial seed leachates that provide the source of carbon and nitrogen in the initial few days but there after the translocation of quantum and nature Pramod Sharma *et al*. (2018).

4.1.2 Plant height (cm)

The data on plant height at 30, 60 DAS and at harvest, as influenced by different nutrients management and seed bio priming and their interactions was presented in Table 4.1, Fig 1 and Plate 4.

4.1.2.1 Plant height at 30 days after sowing (cm)

Plant height was significantly influenced by different nutrient levels at 30 DAS. Among nutrients, the highest plant height of 33.8 cm was attained in nutrient (N_3) 80:50:50 NPK kg ha^{-1} + 2 % DAP spray followed by 80:50:50 NPK kg ha^{-1} + $Feso_4$ spray (N_2:31.52 cm) lower plant height was observed in (N_1) 60:40:20 NPK kg ha^{-1} (27.11 cm).

Among different seed priming with *Pseudomonas fluorescens* (P_3) gave higher plant height (33.45 cm) followed by seed priming with *Trichoderma harzianum* (1.5%) P_2 (30.57 cm) and lower plant height was observed in control P_1 (28.07 cm).

Interaction of both seed treatment and nutrients showed a non-significant difference in plant height, highest was observed in N_3P_3 (36.10 cm) followed by N_4P_3 (35.37 cm) where as lower plant height was observed in N_1P_1 is 25.67 cm.

4.1.2.2 Plant height at 60 days after sowing (cm)

The plant height at 60 days after sowing showed significant difference due to different nutrients. The plant height was maximum (88.72 cm) in 80:50:50 NPK $kgha^{-1}$ + 2 % DAP spray (N_3) and minimum (81.05 cm) in 125 kg neem cake ha^{-1} + 1250 kg vermicompostha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+ 10 kg *Azospirillum* ha^{-1}(N_4).

Difference in plant height at 60 days after sowing was non-significant due to different seed treatment levels. Highest plant height was observed in seed priming with *Pseudomonas fluorescens* (P_3:85.58 cm) whereas lower plant height is observed in (control) P_1 (84.14 cm)

Interaction of both seed bio priming and nutrients showed a significant difference with respect to plant height, highest was observed in N_3P_1 (89.50 cm)

followed by N_3P_3 (88.83 cm) whereas lower plant height was observed in N_4P_1 is 80.17 cm.

4.1.2.3 Plant height at harvest (cm)

The plant height at harvest showed significant difference due to different nutrients. The maximum plant height of 90.47 was recorded in 80:50:50 NPK kg ha^{-1} + 2 % DAP spray (N_3) a minimum plant height (84.30 cm) was recorded under 125 kg neem cake ha^{-1} + 1250 kg vermicompost ha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+ 10 kg *Azospirillum* ha^{-1} (N_4).

Non-significant difference in plant height resulted due to difference of seed treatment levels. Highest was observed in seed priming with *Pseudomonas fluorescens* (P_3;90.05 cm) whereas lower plant height was observed in (control) P_1 is 86.49 cm.

Non-significant difference was noticed in plant height at harvest. However, in the interaction of nutrients and seed treatment, the maximum plant height was recorded in N_3P_3 (91.80 cm), while the minimum plant height was recorded in N_4P_1 (82.52 cm).

Interaction nutrient application (NPK 80:50:50 kg ha^{-1}+ 2 % DAP spray) and seed bio priming with 20 % liquid *Pseudomonas fluorescens* recorded highest plant height at 30, days and at harvest (36.10 cm and 91.80 cm, respectively). They showed that foliar application of 2 % DAPS increases the plant height of Quinoa. The promotion of growth in terms of increase in plant height has been due to increasing plasticity of cell wall followed by hydrolysis of starch to sugars whichlowers the water potential of cell, resulting in the entry of water into cell causing elongation. This osmotic driven response under the influence of gibberellins might have been attributed to increase in photosynthetic activity, accelerated translocation and efficiency of utilizing the photosynthetic products, thus resulting increases cell elongation and raped cell division in the growing parts in proso millet (Turgut *et al*., 2006).

Table 4.1 Influence of nutrient levels and seed bio priming on field emergence and plant height at 30, 60 DAS and at harvest stage in quinoa *cv*. EC 507740

Treatments	Field emergence (%)	Plant height (cm)		
		30 DAS	60 DAS	At harvest
Nutrient levels (N)				
N_1: 60:40:20 NPK kg ha^{-1}	85.11	27.11	84.46	87.73
N_2: 80:50:50 NPK kg ha^{-1} + 2 % $FeSO_4$ spray	87.00	31.52	85.38	89.12
N_3: 80: 50: 50 NPK kg ha^{-1} + 2 % DAP spray	88.44	33.8	88.72	90.47
N_4: 125kg Neem cake ha^{-1}+ 1250 kg Vermicompost ha^{-1} + 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1} + 10 kg *Azospirillum*ha^{-1}	84.89	30.36	81.05	84.30
S.Em. ±	0.69	1.26	0.51	1.41
CD (P = 0.05)	2.05	3.67	1.52	4.14
Priming treatments (P)				
P_1 : Control	85.50	28.07	84.14	86.49
P_2: Seed priming with *Trichoderma harzianum* (1.5%)	86.17	30.57	84.99	87.17
P_3: Seed priming with (20 %) liquid *Pseudomonas fluorescens*	87.41	33.45	85.58	90.05
S.Em. ±	0.61	1.09	0.44	1.22
CD (P = 0.05)	**NS**	3.20	**NS**	**NS**
Interaction (NXP)				
N_1P_1	84.00	25.67	80.42	84.45
N_1P_2	84.67	27.67	87.15	88.49
N_1P_3	86.67	28.00	85.83	90.27
N_2P_1	85.00	28.80	86.50	87.57
N_2P_2	88.67	31.43	83.83	88.43
N_2P_3	87.33	34.33	85.83	91.37
N_3P_1	86.67	31.50	89.50	91.45
N_3P_2	87.67	33.80	87.83	88.18
N_3P_3	91.00	36.10	88.83	91.80
N_4P_1	86.33	26.33	80.17	82.52
N_4P_2	83.67	29.40	81.17	83.60
N_4P_3	84.67	35.37	81.83	86.79
S.Em. ±	1.211	2.18	0.89	2.44
CD (P = 0.05)	**NS**	**NS**	**1.60**	**NS**
CV (%)	2.43	12.32	1.83	4.81

NS: Non-significant

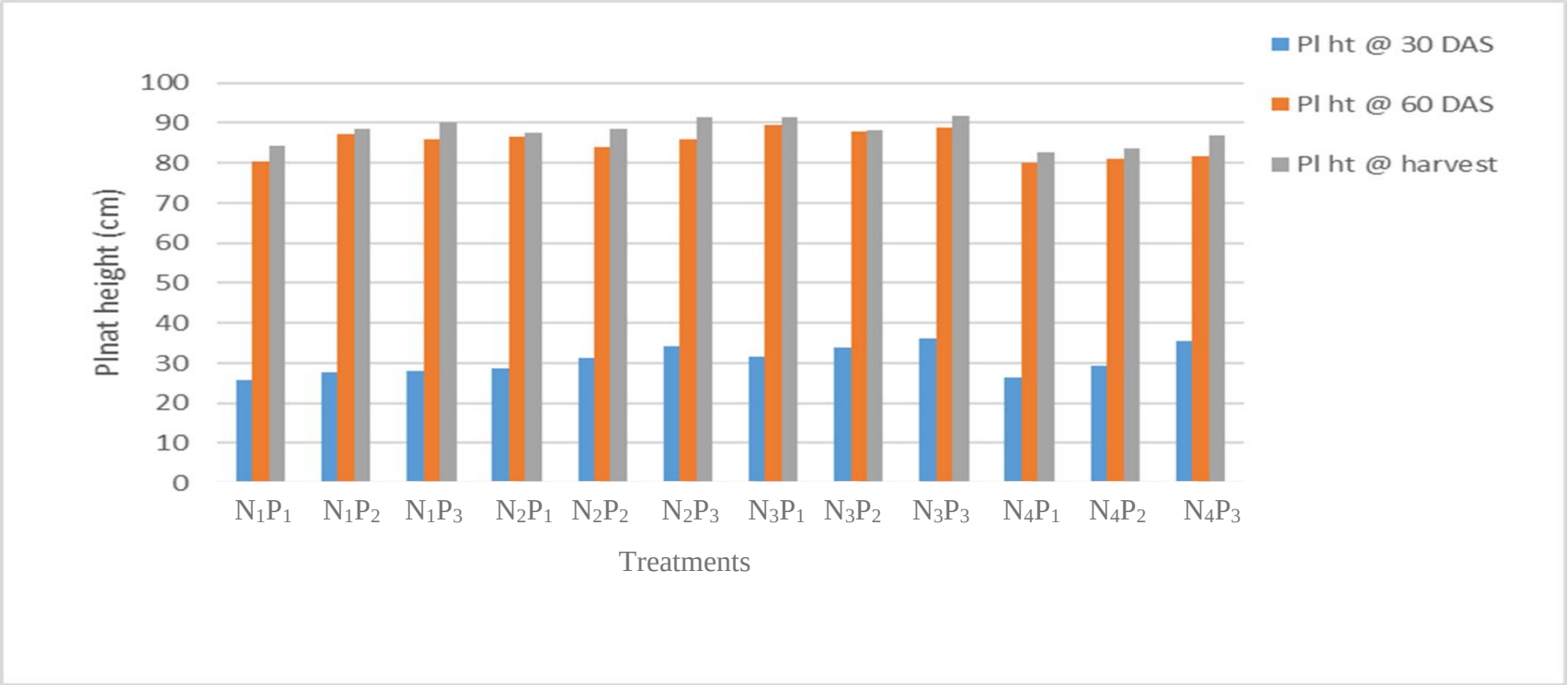

Fig. 2: Influence of nutrient levels and seed bio-priming on plant height at 30, 60 DAS and at harvest in quinoa.

Treatment details:

I. Nutrient levels (N)

N_1 :60:40:20 NPK kg ha^{-1}

N_2 : 80: 50: 50 NPK kg ha^{-1}+2 % $Feso_4$ spray at flowering

N_3 : 80: 50: 50 NPK kg ha^{-1}+ 2 % DAP spray at pre-flowering

N_4 : 125 kg neem cake ha^{-1} + 1250 kg vermin compost ha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+10 kg *Azospirillum* ha^{-1}

II. Seed bio priming (P)

P_1 : Control

P_2 : Seed priming: with *T. harzianum* (1.5 %) (6hr)

P_3 : Seed priming with 20 % liquid *Pseudomonas fluorescence*(6 hr)

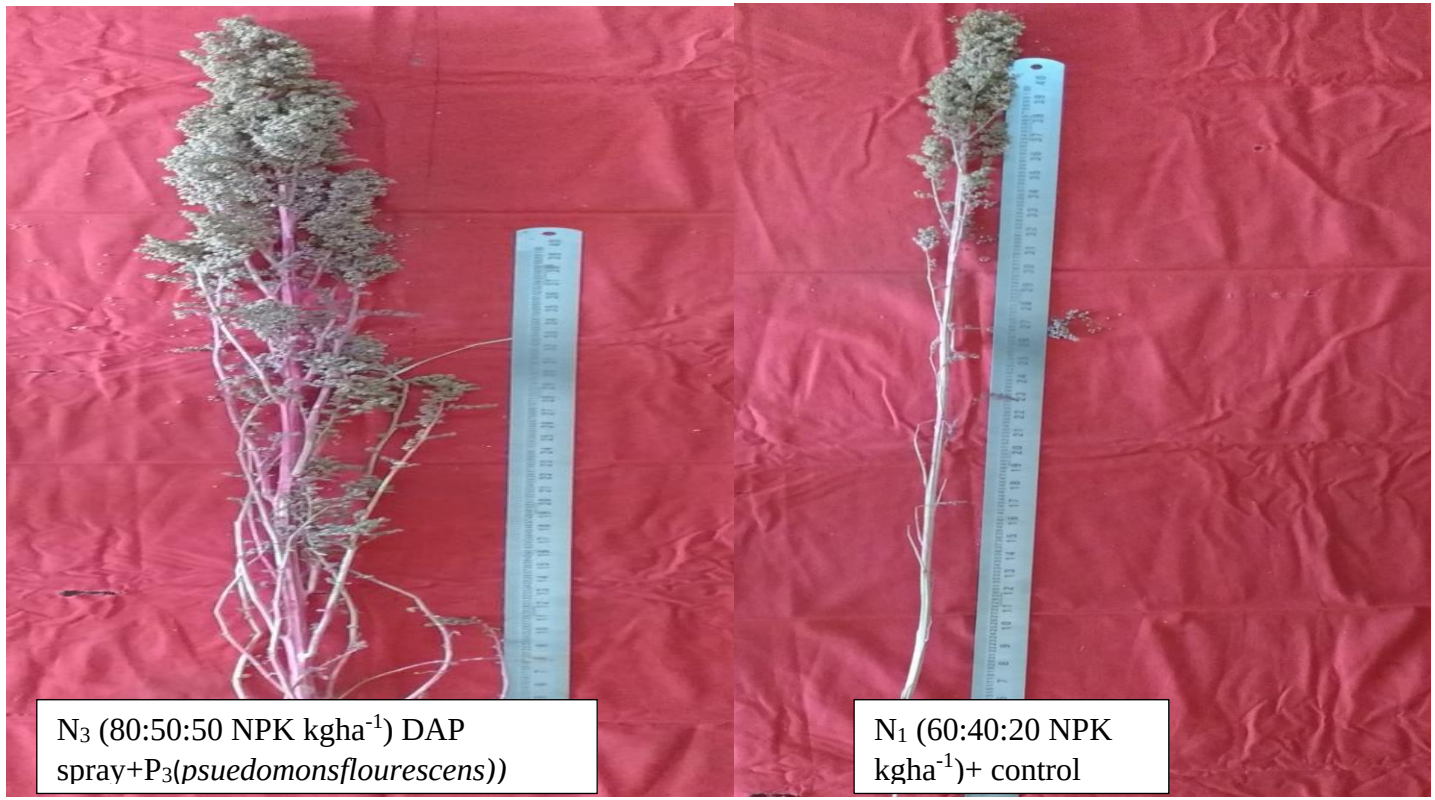

Plate 4:Influence of nutrients levels and seed bio-priming on plant height at harvest in Quinoa

4.1.2.4 Days to 50 per cent flowering

The data on day to 50 per cent flowering as influenced by nutriments levels and seed bio priming are presented in table 4.2.

Days to 50 per cent flowering differed non-significantly due to different nutrients and minimum number of days taken to 50 per cent flowering (40.55) was observed in 80:50:50 NPK kg ha^{-1} +2 % DAP spray (N_3) and where 125 kg neem cake ha^{-1} + 1250 kg vermicompostha^{-1}+ 10 kg PSB ha^{-1}+ 10 kg KSB ha^{-1}+ 10 kg *Azospirillum* ha^{-1} (N_4) took maximum number of days for 50 % flowering (42.22).

Non-significant difference was observed for days to 50 per cent flowering differed non-significantly due to different seed treatment and minimum number of days taken to 50 per cent flowering (40.23) was observed in seed priming: with *Trichoderma harzianum* (1.5 %) (P_2) and where P_1 (control) took maximum number of days for 50 % flowering (41.66).

There was no significant difference noticed between nutrients levels and seed bio priming for days to 50 per cent flowering. However, in the interaction of nutrients and seed treatment, the minimum number of days taken to 50 % flowering (N_3P_2) 40 days and maximum days took for 50 % flowering as recorded in T_1(43) days. In the present investigation, it was observed that NPK (60:40:20 kg $ha^{-1)}$ and uncontrolled seed recorded maximum number of days to 50 per cent flowering (43) These results are in agreement with those reported by (Anitha *et al*. 2015) in soybean.

4.1.2.5 Days to maturity

The data on days to maturity as influenced by different nutrients and seed priming treatment are presented in table 4.2.

Significant difference was observed for days to maturity due to different nutrient management among125 kg neem cake ha^{-1} + 1250 kg vermicompost ha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+ 10 kg *Azospirillum* ha^{-1} (N_4) took maximum days for maturity (92.22) and 80:50:50 NPK kg ha^{-1} + 2 % DAP spray (N_3) took less days to maturity (89.89).

Non-significant difference was observed on days to maturity due to different seed treatment however, unprimed seeds P_1 (92.08) took more number of days followed by *Trichoderma harzianum* (1.5 %) P_2 (92.08) days while less number of days to maturity in seed priming with 20 % liquid *Pseudomonas fluorescens* P_3 (90.91).

Difference due to interaction and seed bio priming found non-significant for days to maturity. However, in the interaction of nutrients and seed treatment, N_1P_1 took maximum number days for maturity 93.33 and N_3P_3 took fewer days to maturity (89.67).

4.2 Yield and yield attributing parameters of quinoa as influenced by nutrient levels and seed bio priming

4.2.1 Total number of panicles plant^{-1}

The data on total number of panicles as influenced by different levels of nutrients and seed treatment are presented in table 4.3.

Total number of panicles plant^{-1} due to different nutrient management was differed significantly and 80:50:50 NPK kg ha^{-1} + 2 % DAP spray (N_3) bears more number of panicles (12.25) followed by N_2 (11.05). The lowest was seen in60:40:20 NPK kg ha^{-1}(9.42).

Significant difference was observed for total number of panicles plant^{-1} and among priming seed treatment with *Pseudomonas fluorescens* (P_3) bears more number of panicles (11.53) followed by P_2 (10.46) and P_1exhibited less number of panicles (10.06).

Non-significant difference was noticed for total number of panicles plant^{-1} due to interaction between nutrition and seed priming. However, in the interaction of nutrients and seed treatment N_3P_3 recorded more number of panicles (13.10) followed by N_3P_2 (12.60) and N_1P_1 recorded as less number of panicles (9.67).

Table 4.2 Influence of nutrient levels and seed bio priming on days to 50 percent flowering and days to maturity in quinoa *cv*. EC 50774

Treatments	Days to 50 % flowering	Days to maturity
Nutrient levels (N)		
N_1: 60:40:20 NPK kg ha ^{1}	40.89	92.22
N_2: 80:50:50 NPK kg ha^{-1} + 2 % $FeSO_4$ spray	41.00	91.11
N_3: 80: 50: 50 NPK kg ha^{-1} + 2 % DAP spray	40.55	89.89
N_4: 125 kg Neem cake ha^{-1}+ 1250 kg Vermicompost ha^{-1} + 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1} + 10 kg *Azospirillum* ha^{-1}	42.22	92.33
S.Em ±	0.44	0.50
CD (P = 0.05)	**NS**	1.47
Priming treatments (P)		
P_1: Control	41.66	92.08
P_2: Seed priming with *Trichoderma harzianum* (1.5%)	40.83	91.16
P_3: Seed priming with (20 %) liquid *Pseudomonas fluorescens*	41.00	90.91
S.Em ±	0.38	0.43
CD (P = 0.05)	**NS**	**NS**
Interaction (NXP)		
N_1P_1	43.00	93.33
N_1P_2	39.67	91.33
N_1P_3	40.00	92.00
N_2P_1	40.67	92.00
N_2P_2	41.67	91.33
N_2P_3	40.67	90.00
N_3P_1	41.00	90.33
N_3P_2	40.00	89.67
N_3P_3	40.67	89.67
N_4P_1	42.00	92.67
N_4P_2	42.00	92.33
N_4P_3	42.67	92.00
S.Em ±	0.77	0.87
CD (P = 0.05)	**NS**	**NS**
CV (%)	3.27	1.65

NS: Non-significant

4.2.2 Total number of branches plant^{-1}

The data on total number of branches plant^{-1} as influenced by different levels of nutrients and seed treatment are presented in table 4.3.

Significant difference was observed fortotal number of branches plant^{-1}. Among nutrients, 80:50:50 NPK kg ha^{-1} + 2 % DAP spray (N_3:12.95) recorded more number of branches plant^{-1} followed by N_2 (11.98) and60:40:20 NPK kg ha^{-1}(N_1) recorded less number of branches plant^{-1} (9.37).

Total number branches plant^{-1} had a significant difference due to seed priming. Among seed priming treatment, priming with *Pseudomonas fluorescens* (P_3) recorded more number of branches (12.01) followed by P_2 (11.36) and P_1 (control) recorded less number of branches plant^{-1}.

Difference due to interaction between nutrient level and seed priming treatments were found non-significant for number of branches per plant. Total number of branches plant^{-1}. However, N_3P_3 recorded more number of branches (14.47) followed by N_3P_2 (13.13); and N_1P_1 recorded as less number of branches plant^{-1} (9.33).

The increase in plant height and number of branches per plant with foliar spray of 2 % DAP fertilizers might be due to improved photosynthetic efficiency. These results are in close conformity with the findings of Kumar and Uppar (2010) in mothbean.

4.2.3 Panicle length of main stem (cm)

The data pertaining to panicle length of main stem as influenced by different levels of nutrients and seed treatment are presented in table 4.3.

Panicle length of main stem showed non-significant difference due to different nutrients. Among the nutrient levels 80:50:50 NPK kg ha^{-1} + 2 % DAP spray (N_3) recorded maximum length of panicle (30.05 cm) and 125 kg neem cake ha^{-1} + 1250 kg vermicompostha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+ 10 kg *Azospirillum* ha^{-1} (N_4) recorded minimum length of panicle (27.57 cm)

Among seed bio-priming, panicle length of main stem didn't differed significantly. However, P_1 recorded maximum panicle length (28.41 cm) and priming with *Trichoderma harzianum* (1.5 %;P_2) recorded minimum panicle length (28.00 cm).

Interactions of seed bio priming and nutrient levels were found to be significant for panicle length of main stem. However, N_3P_3 recorded long panicle length (32.57 cm) and shortest was in N_1P_1 (24.93 cm).

Total number branches plant^{-1}, total number of panicles plant^{-1}, panicle length of main stem was significantly influenced by nutrient levels and seed priming. Application of 80: 50: 50 NPK kg ha^{-1} + 2 % DAP spray at pre-flowering with seed treated with *pseudomonas fluorescens* exerted favorable influence and improved all the yield attributes. Increase in level of nitrogen application will increase the number of filled grains panicle^{-1}which might be due to higher availability of N at panicle initiation and grain development stages as reported by Channabasavanna *et al*., (2008).

4.2.4 Panicle dry weight (main + secondary) plant^{-1} in (gm)

The data on panicle dry weight per plant as influenced by levels of nutrition and seed bio priming and their interaction are presented in table 4.4.

Panicle dry weight per plant differed non-significant among different nutrient levels. Maximum dry weight (25.31 g) of panicle was observed in 80:50:50 NPK kgha^{-1} + 2 % DAP spray (N_3) while, minimum (20.15 g) was noticed in 60:40:20 NPK kg ha^{-1} (N_1).

Seed priming treatments showed non-significant difference for panicle dry weight per plant. Maximum panicle dry weight was recorded in seed priming with *Pseudomonas fluorescens* (P_3:23.65 g) and minimum was observed in P_1 (control: 20.89 g)

Interaction of nutrient level and primed seeds were found non-significant on panicle dry weight and however, N_3P_3 recorded highest panicle dry weight (27.13 g) and N_1P_1recorded less dry weight of panicle (14.80 g).

Table 4.3 Influence of nutrient levels and seed bio priming on total number of panicles plant^{-1}, total number of branches plant^{-1}and panicle length of main stem in quinoa *cv*. EC 507740

Treatments	Total number of branches plant^{-1}	Total number of panicles plant^{-1}	Panicle length of main stem (cm)
Nutrient levels (N)			
N_1: 60:40:20 NPK kg ha^{-1}	9.37	9.42	28.31
N_2: 80:50:50 NPK kg ha^{-1} + 2 % $FeSO_4$ spray	11.98	11.05	27.06
N_3: 80: 50: 50 NPK kg ha^{-1} + 2 % DAP spray	12.95	12.25	30.05
N_4: 125 kg Neem cake ha^{-1}+ 1250 kg Vermicompost ha^{-1} + 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1} + 10 kg *Azospirillum* ha^{-1}	11.75	10.01	27.57
S.Em ±	0.58	0.42	1.24
CD (P = 0.05)	1.70	1.25	**NS**
Priming treatments (P)			
P_1: Control	11.16	10.06	28.41
P_2: Seed priming with *Trichoderma harzianum*(1.5%)	11.36	10.46	28.00
P_3: Seed priming with (20 %) liquid *Pseudomonas fluorescens*	12.01	11.53	28.34
S.Em ±	0.50	0.37	1.08
CD (P = 0.05)	1.47	1.08	**NS**
Interaction (NXP)			
N_1P_1	9.33	9.67	24.93
N_1P_2	8.20	8.47	32.00
N_1P_3	10.60	10.13	28.00
N_2P_1	11.47	10.73	31.00
N_2P_2	12.67	10.93	25.87
N_2P_3	11.80	11.50	24.33
N_3P_1	11.27	11.07	29.60
N_3P_2	13.13	12.60	28.00
N_3P_3	14.47	13.10	32.57
N_4P_1	12.60	8.77	28.13
N_4P_2	11.47	9.87	26.13
N_4P_3	11.20	11.40	28.47
S.Em ±	1.00	0.74	2.16
CD (P = 0.05)	**NS**	**NS**	**NS**
CV (%)	16.26	12.64	13.26

NS: Non-Significant

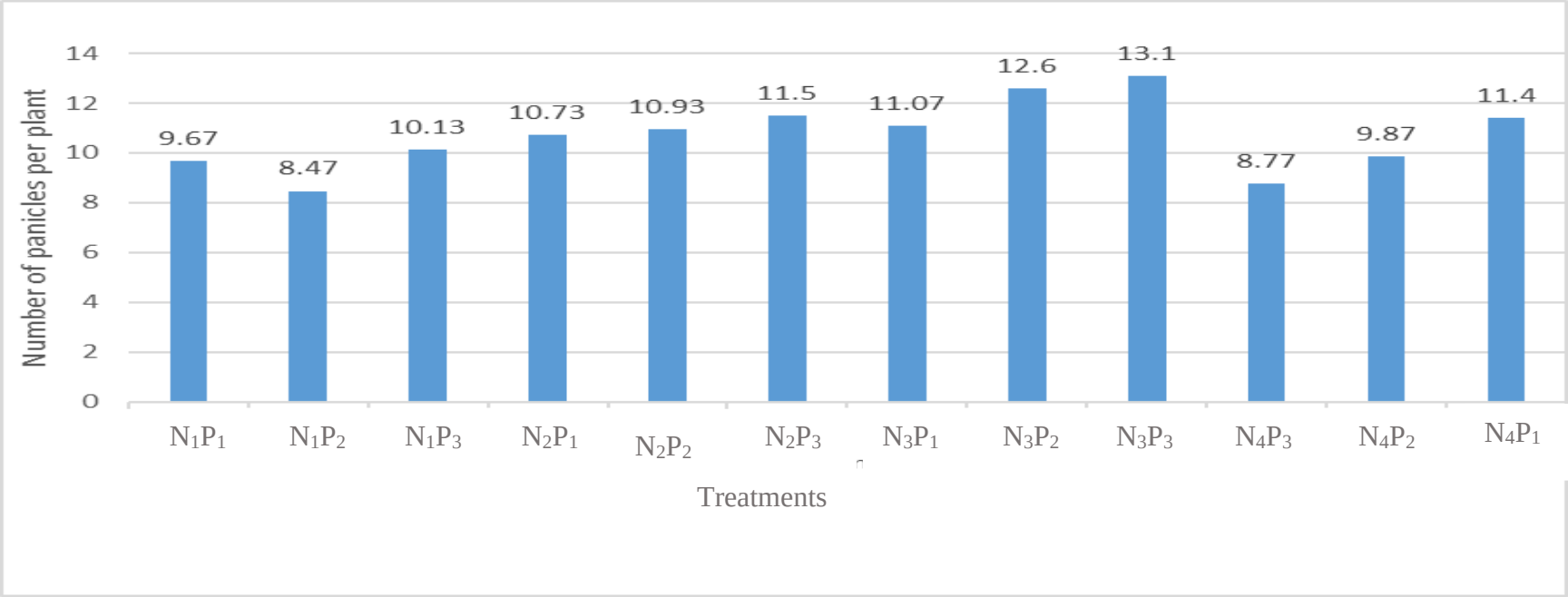

Fig. 3: Influence of nutrients levels and seed bio-priming on number of panicles plant^{-1} in quiona

Treatment details:

I. Nutrient levels (N)

N_1 :60:40:20 NPK kg ha^{-1}

N_2 : 80: 50: 50 NPK kg ha^{-1}+2 % $Feso_4$ spray at flowering

N_3 : 80: 50: 50 NPK kg ha^{-1}+ 2 % DAP spray at pre-flowering

N_4 : 125 kg neem cake ha^{-1} + 1250 kg vermin compost ha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+10 kg *Azospirillum* ha^{-1}

II. Seed bio priming (P)

P_1 : Control

P_2 : Seed priming: with *T. harzianum* (1.5 %) (6hr)

P_3 : Seed priming with 20 % liquid *Pseudomonas fluorescence*(6 hr)

Plate 5: Influence of nutrient levels and seed bio-priming on panicle length of main stem

4.2.5 Seed yield plant^{-1}

The data on seed yield per plant as influenced by levels of nutrition and seed bio priming and their interaction are presented in table 4.4.

Seed yield per plant differed non-significantly. 80:50:50 NPK kg ha^{-1} + 2 % DAP spray (N_3) recorded more seed yield per plant (6.49 g) and60:40:20 NPK kg ha^{-1} (N_1) recorded as least seed yield per plant (4.53 g).

Seed yield per plant had significant difference in seed bio priming treatment. *Pseudomonas fluorescens* (P_3) recorded more seed yield per plant (5.97 g) and P_1 (control) seeds recorded least seed yield per plant (5.41 g).

The interaction of nutrients and primed seeds found non-significant on seed yield per plant.

4.2.6 Seed yield plot^{-1}

The data on seed yield per plot as influenced by nutrient level and seed treatment and their interaction are presented in table 4.5.

Seed yield per plot differed non-significantly due to different nutrient level. Maximum seed yield per plot (1.44 kg) was noticed in 80:50:50 NPK kg ha^{-1} + 2 % DAP spray (N_3) and minimum seed yield per plot (1.31 kg) was recorded in125 kg neem cake ha^{-1} + 1250 kg vermicompost ha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+ 10 kg *Azospirillum* ha^{-1} (N_4).

Non-significant difference was observed with respect to seed yield per plot due to seed priming treatments. However, P_3 recorded higher seed yield per plot (1.34 kg/plot), while minimum yield was observed in unprimed/control P_1 (1.32 kg/plot)

Influence of different nutrient levels and seed bio priming exhibited non-significant effect on seed yield per plot. Maximum seed yield per plot (1.58 kg) was recorded in (N_3P_3) and minimum seed yield per plot (1.27 kg) was recorded in N_4P_1.

Table 4.4 Influence of nutrient levels and seed bio-priming on panicle dry weight (main + secondary) plant^{-1} and seed yield plant^{-1} in quinoa *cv.* EC 507740

Treatments	Panicle dry weight (g)	Seed yield plant^{-1} (g)
Nutrient levels (N)		
N_1: 60:40:20 NPK kg ha^{-1}	20.15	4.53
N_2: 80:50:50 NPK kg ha^{-1} + 2 % $FeSO_4$ spray	22.40	5.84
N_3: 80: 50: 50 NPK kg ha^{-1} + 2 % DAP spray	25.31	6.49
N_4: 125 kg Neem cake ha^{-1}+ 1250 kg Vermicompost ha^{-1} + 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1} + 10 kg *Azospirillum* ha^{-1}	20.51	5.89
S.Em ±	2.35	0.13
CD (P = 0.05)	**NS**	**0.40**
Priming treatments (P)		
P_1: Control	21.73	5.41
P_2: Seed priming with *Trichoderma harzianum* (1.5%)	20.89	5.72
P_3: Seed priming with (20 %) liquid *Pseudomonas fluorescens*	23.65	5.97
S.Em ±	2.03	0.12
CD (P = 0.05)	**NS**	**0.35**
Interaction (NXP)		
N_1P_1	14.80	4.27
N_1P_2	24.33	4.37
N_1P_3	21.33	4.97
N_2P_1	25.93	5.53
N_2P_2	20.20	5.90
N_2P_3	21.07	6.10
N_3P_1	23.67	6.13
N_3P_2	25.13	6.37
N_3P_3	27.13	6.97
N_4P_1	22.53	5.73
N_4P_2	13.93	6.07
N_4P_3	25.07	5.87
S.Em ±	4.07	0.24
CD (P = 0.05)	**NS**	**NS**
CV (%)	8.6	7.36

NS: Non-significant

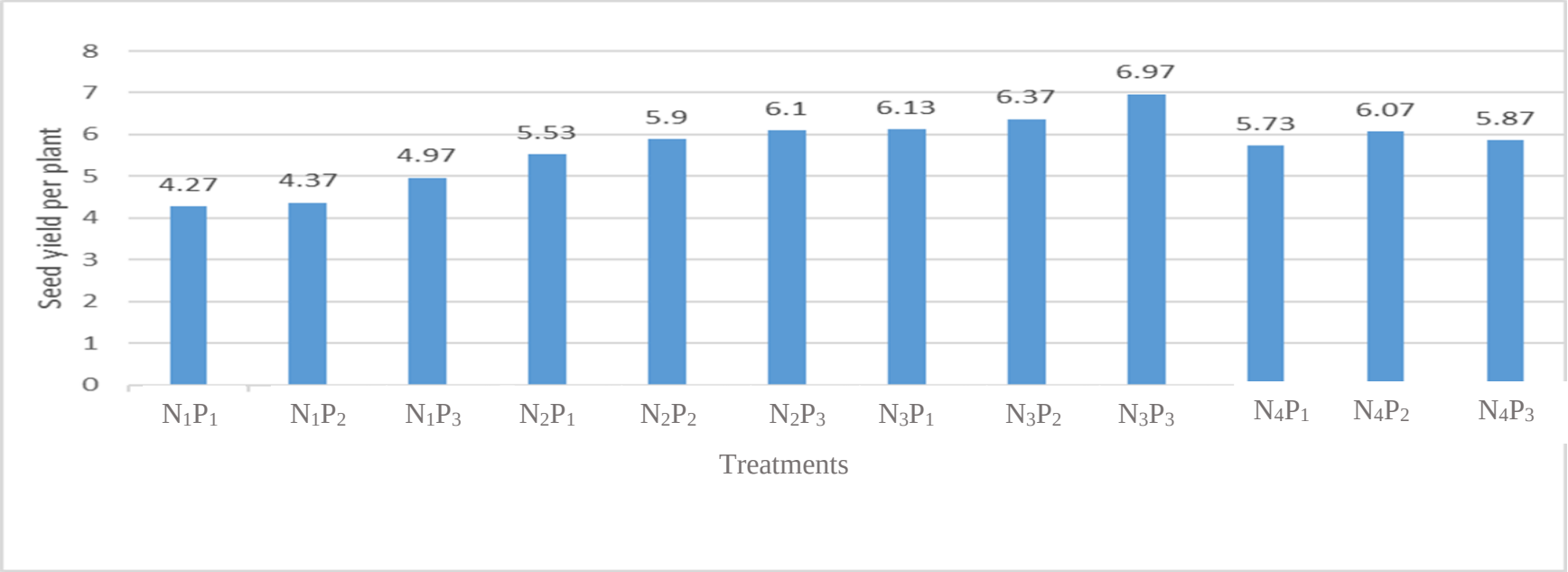

Fig. 4: Influence of nutrient levels and seed bio-priming on seed yield plant^{-1} in quinoa

Treatment details:

I. Nutrient levels (N)

N_1 :60:40:20 NPK kg ha^{-1}

N_2 : 80: 50: 50 NPK kg ha^{-1}+2 % $Feso_4$ spray at flowering

N_3 : 80: 50: 50 NPK kg ha^{-1}+ 2 % DAP spray at pre-flowering

N_4 : 125 kg neem cake ha^{-1} + 1250 kg vermin compost ha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+10 kg *Azospirillum* ha^{-1}

II. Seed bio priming (P)

P_1 : Control

P_2 : Seed priming: with *T. harzianum* (1.5 %) (6hr)

P_3 : Seed priming with 20 % liquid *Pseudomonas fluorescence*(6 hr)

4.2.7 1000 seed weight (g)

The data on 1000 seed weight as influenced by nutrient level and priming treatment and their interactions are presented in table 4.5

Non-significant differences were observed for 1000 seed weight in different nutrient levels. The highest 1000 seed weight (2.91 g) was recorded in 80:50:50 NPK kgha^{-1} + 2 % DAP spray (N_3) and minimum 1000 seed weight of (2.79 g) was noticed in 125 kg neem cake ha^{-1} + 1250 kg vermicompostha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+ 10 kg *Azospirillum* ha^{-1} (N_4).

Non-Significant differences were observed for 1000 seed weight in seed bio-priming treatment. Among the different priming treatment, seed priming with *Pseudomonas fluorescens* (P_3) recorded the maximum 1000 seed weight (2.87 g) while, the minimum 1000 seed weight (2.82 g) was noticed in (control; P_1).

Non significant differences were observed for 1000 seed weight for the interaction of nutrient levels and priming treatment. However, maximum 1000 seed weight was recorded in N_3P_3:2.99 g while, minimum 1000 seed weight was recorded under N_4P_3 (2.65 g).

Increase in nitrogen levels results in increased grain yield might be due to formation of more leaf area, which may have intercepted more light and produced more carbohydrates in the source which probably translocated into the sink (the grain) and resulted in increased seed weight than the control.

The present results are in conformity with Jayashri (2016) that increasing N rates increases the enzymes activity in maize which may result in higher kernel weight. In other words N stress probably distributed the source and sink relationship.

4.2.8 Seed yield per hectare (q)

The data pertaining to seed yield per hectare as influenced by nutrient level and priming treatments and their interactions are depicted in table 4.5.

The influence of nutrient levels on seed yield per hectare differed significantly. The maximum seed yield per hectare was recorded under 80:50:50 NPK kgha^{-1} + 2 % DAP spray (N_3:14.47 q) and minimum seed yield per hectare was

Table 4.5 Influence of nutrient levels and seed bio priming on seed yield plot^{-1}, 1000 seed weight and seed yield in quinoa *cv*. EC 50774

Treatments	Seed yield plot^{-1} (kg)	1000 seed weight (g)	Seed yield (q/ha)
Nutrient levels (N)			
N_1: 60:40:20 NPK kg ha^{-1}	1.32	2.83	12.37
N_2: 80:50:50 NPK kg ha^{-1} + 2 % $FeSO_4$ spray	1.30	2.88	13.98
N_3: 80: 50: 50 NPK kg ha^{-1} + 2 % DAP spray	1.44	2.91	14.47
N_4: 125 kg Neem cake ha^{-1}+ 1250 kg Vermicompost ha^{-1} + 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1} + 10 kg *Azospirillum* ha^{-1}	1.31	2.79	13.85
S.Em ±	0.07	00.5	0.18
CD (P = 0.05)	**NS**	**NS**	**0.52**
Priming treatments (P)			
P_1 : Control	1.32	2.82	13.38
P_2: Seed priming with *Trichoderma harzianum*(1.5%)	1..34	2.86	13.41
P_3: Seed priming with (20 %) liquid *Pseudomonas fluorescens*	1.35	2.87	14.21
S.Em ±	0.06	0.04	0.15
CD (P = 0.05)	**NS**	**NS**	**0.45**
Interaction (NXP)			
N_1P_1	1.32	2.83	11.38
N_1P_2	1.38	2.80	12.37
N_1P_3	1.28	2.86	13.37
N_2P_1	1.32	2.83	14.17
N_2P_2	1.21	2.92	13.50
N_2P_3	1.21	2.89	14.27
N_3P_1	1.37	2.81	14.33
N_3P_2	1.43	2.93	14.17
N_3P_3	1.52	2.99	14.93
N_4P_1	1.27	2.82	13.67
N_4P_2	1.36	2.80	13.63
N_4P_3	1.31	2.77	14.27
S.Em ±	0.12	0.09	0.31
CD (P = 0.05)	**NS**	**NS**	**NS**
CV (%)	15.93	**6.06**	**3.96**

NS: Non-Significant

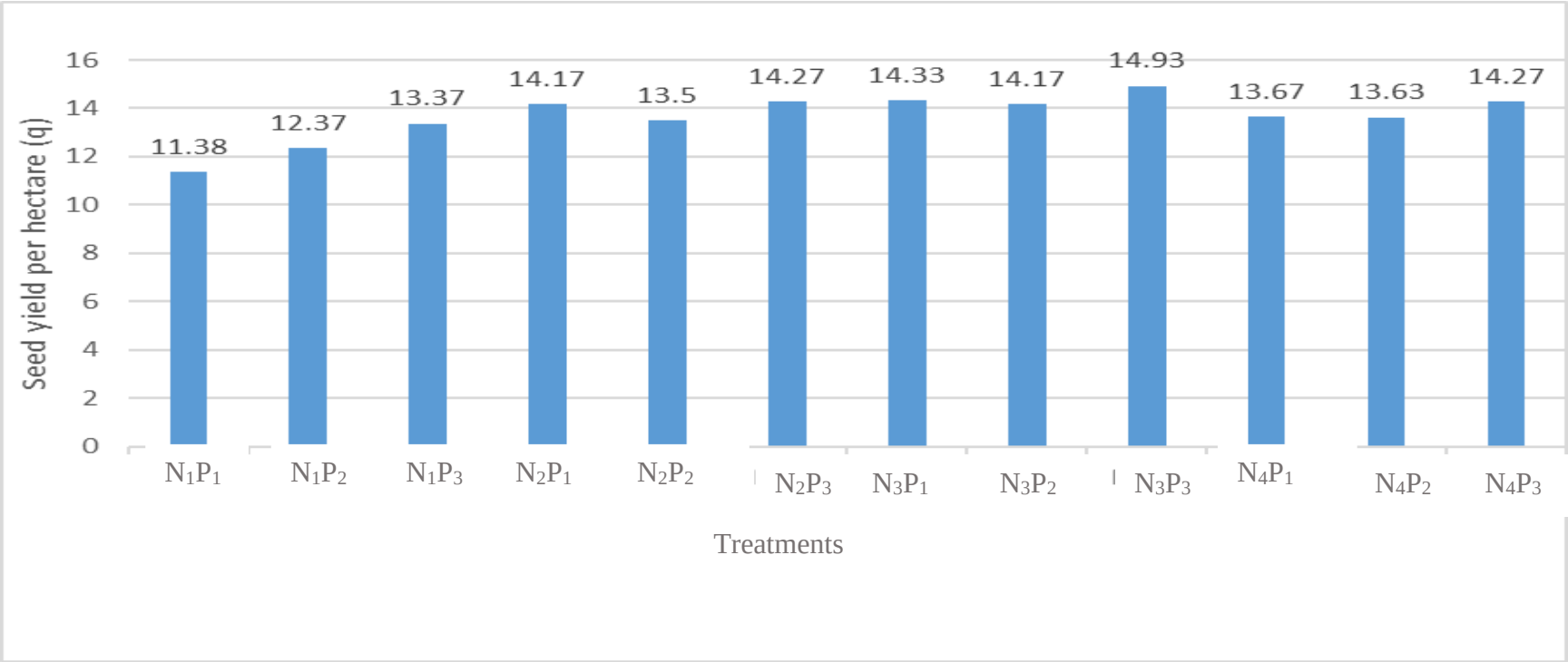

Fig. 5: Influence of nutrient levels and seed bio-priming on seed yield ha^{-1}

Treatment details:

I. Nutrient levels (N)

N_1 :60:40:20 NPK kg ha^{-1}

N_2 : 80: 50: 50 NPK kg ha^{-1}+2 % $Feso_4$ spray at flowering

N_3 : 80: 50: 50 NPK kg ha^{-1}+ 2 % DAP spray at pre-flowering

N_4 : 125 kg neem cake ha^{-1} + 1250 kg vermin compost ha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+10 kg *Azospirillum* ha^{-1}

II. Seed bio priming (P)

P_1 : Control

P_2 : Seed priming: with *T. harzianum* (1.5 %) (6hr)

P_3 : Seed priming with 20 % liquid *Pseudomonas fluorescence*(6 hr)

noticed in 60:40:20 NPK kg ha^{-1} (N_1:12.37 q). Seed yield per hectare showed significant differences due to different priming treatment. Maximum seed yield per hectare (14.2 q) was recorded in seed priming with *Pseudomonas fluorescens* (P_3) and minimum seed yield per hectare (13.38 q) was noticed in control (P_1).

The interaction effect of nutrient levels and priming treatments regarding seed yield per hectare found to be non-significant. However, maximum seed yield (14.93q) was noticed in (N_3P_3) and minimum seed yield per ha (11.38 q) was recorded in N_1P_1. Among various nutrient management practices application of 80:50:50 NPK $kgha^{-1}$ + 2 % DAP spray at pre-flowering stage recorded significantly higher panicle dry weight (25.31 g), seed yield per plant (6.49 g), seed yield per plot (1.44 kg) and 1000 seed weight (2.91 g) leads to the higher seed yield per hectare (14..47 q).

The main advantage of inorganic fertilizers over organic fertilizers is that they can be used immediately to rescue dying plants. This is because they are straight fertilizer and the plants easily absorb the nutrients present in them. It is an established fact that nitrogen promotes the vegetative growth consequently up to an optimum levels resulting in more yields. Phosphorous and potassium are also responsible for better growth, maturity and seed yield. All these three nutrients affected positively on the performance of plant and yield contributing traits which resulted in higher seed yield $plant^{-1}$. These findings are in agreement with the results of Jyothi *et al*. (2016) in foxtail millet and Bhomte *et al*. (2016) in little millet.

Among three different priming treatments, seeds priming with *Pseudomonas fluorescens* (20 %) recorded significantly higher seed yield ha^{-1} in this study mainly due to the higher seed yield $plant^{-1}$, seed yield $plot^{-1}$ and 1000 seed weight of this experiment.

Seed priming is a pre-sowing treatment, which leads to a physiological state that enables seed to germinate more efficiently. The majority of seed treatments are based on seed imbibitions allowing the seeds to go through the first stage of germination but do not allow radical protrusion through the seed coat. The priming with *P. fluoresces* was evident in improving the seed yield and yield attributing factors in pearl millet reported by Raj *et al*. (2004).

4.3 Seed quality parameters of quinoa as influenced by the nutrient levels and seed bio priming treatments

4.3.1 Seed germination (%)

The results pertaining germination as influenced by nutrient levels priming treatments and their interaction are presented in table 4.6 and plate 6.

Significant difference was observed due to different nutrients levels for seed germination, 80:50:50 NPK kgha^{-1} + 2 % DAP spray (N_3) recorded highest germination (89.82 %) and least germination was recorded in 60:40:20 NPK kg ha^{-1} (N_1:84.49 %).

Non-significant difference exhibited forseed bio-priming treatments with respect to germination. The highest germination was found in seed priming with *Pseudomonas fluorescens* (P_3:87.41 %) and least germination was recorded in P_1;86.26 %.

Germination percentage showed non-significant differences due to interaction effects of nutrient levels and priming treatment. However, highest germination was registered in N_3P_3:90.05 % and lowest germination was noticed under N_1P_1:82.83 %. The priming with *P.fluorescens* was evident in improving the seed germination and seedling vigour in pearl millet by Raj *et al*. (2004). The enhancement in the seedling growth noticed in this study could be attributed to suppression of deleterious microorganisms and pathogens; production of plant growth regulators such as gibberellins, cytokinins and indole acetic acid, which increased the availability of minerals and others ions and more water uptake (Ramamoorthy *et al.* 2001)

4.3.2 Root length (cm)

The results pertaining on root length as influenced by nutrient levels and priming treatments and their interaction are presented in table 4.6.

Non-significant difference was observed due to different nutrients levels for root length. Treatment 80:50:50 NPK kg ha^{-1} + 2 % DAP spray (N_3) recorded highest root length (6.10 cm) and least root length (5.67 cm) was recordedin 125 kg neem

cake ha^{-1} + 1250 kg vermicompost ha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+ 10 kg *Azospirillum* ha^{-1}(N_4).

Root length had significant difference among the different priming treatments. The highest root length was found in seed priming with *Pseudomonas fluorescens* (P_3:6.05 cm) and least root length was recorded in control: 5.53 cm.

Root length showed non-significant differences due to interaction effects of nutrient levels and priming treatment. However, highest root length was registered in (N_3P_3:6.23 cm) and lowest root length was noticed under N_4P_1 (5.47 cm).

4.3.3 Shoot length (cm)

The data pertaining on shoot length as influenced by nutrient levels, priming treatments and their interaction are presented in table 4.6.

Non-significant difference for shoot length was observed due to different nutrients levels, 80:50:50 NPK kg ha^{-1} + 2 % DAP spray (N_3) recorded highest shoot length (5.49 cm) and least shoot length was recorded under 60:40:20 NPK kg ha^{-1}(N_1:5.34 cm).

Significant differences was observed in shoot length with respect to different priming treatments. The highest shootlength was found in seed priming with *Pseudomonas fluorescens* (P_3:5.47 cm) and least shoot length was recorded in control, P_1 (5.34 cm).

Shoot length showed non-significant differences due to interaction effects of nutrient levels and priming treatments. However, highest shoot length was registered in N_3P_3 (5.70 cm) and lowest shoot length was noticed under N_1P_1(5.19 cm).

4.3.4 Mean seedling length (cm)

The results pertaining to mean seedling length as influenced by nutrient levels priming treatments and their interaction are presented in table 4.7 and plate 7.

Effect of different nutrient levels had non-significant effect on mean seedling length. The highest mean seedling length of 11.65 cm was noticed under 80:50:50 NPK kgha^{-1} + 2 % DAP spray (N_3) and lowest (11.15 cm) was recorded under125 kg

Table 4.6 Influence of nutrient levels and seed bio priming on germination (%), root length (cm) and shoot length (cm) in quinoa*cv*. EC 507740

Treatments	Germination (%)	Root length (cm)	Shoot length (cm)
Nutrient levels (N)			
N_1: 60:40:20 NPK kg ha^{-1}	84.49	5.93	5.34
N_2: 80:50:50 NPK kg ha^{-1} + 2 % $FeSO_4$ spray	88.00	5.78	5.42
N_3: 80: 50:50 NPK kg ha^{-1} + 2 % DAP spray	89.82	6.10	5.49
N_4: 125 kg Neem cake ha^{-1}+ 1250 kg Vermicompost ha^{-1} + 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1} + 10 kg *Azospirillum* ha^{-1}	85.25	5.67	5.40
S.Em ±	0.77	0.15	0.17
CD (P = 0.05)	**2.28**	**NS**	**NS**
Priming treatments (P)			
P_1 : Control	86.26	5.53	5.34
P_2: Seed priming with *Trichoderma harzianum* (1.5%)	87.11	6.03	5.43
P_3: Seed priming with (20 %) liquid *Pseudomonas fluorescens*	87.41	6.05	5.47
S.Em ±	0.67	0.13	0.15
CD (P = 0.05)	**NS**	**0.38**	**NS**
Interaction (NXP)			
N_1P_1	82.83	5.48	5.19
N_1P_2	85.83	6.21	5.53
N_1P_3	84.83	6.10	5.30
N_2P_1	87.87	5.27	5.35
N_2P_2	89.07	6.03	5.47
N_2P_3	89.17	6.05	5.46
N_3P_1	89.17	5.92	5.34
N_3P_2	88.17	6.17	5.44
N_3P_3	90.50	6.23	5.70
N_4P_1	85.20	5.47	5.50
N_4P_2	85.40	5.71	5.28
N_4P_3	85.17	5.85	5.42
S.Em ±	1.34	0.26	0.31
CD (P = 0.05)	**NS**	**NS**	**NS**
CV (%)	**2.68**	**7.79**	**9.96**

NS: Non-Significant

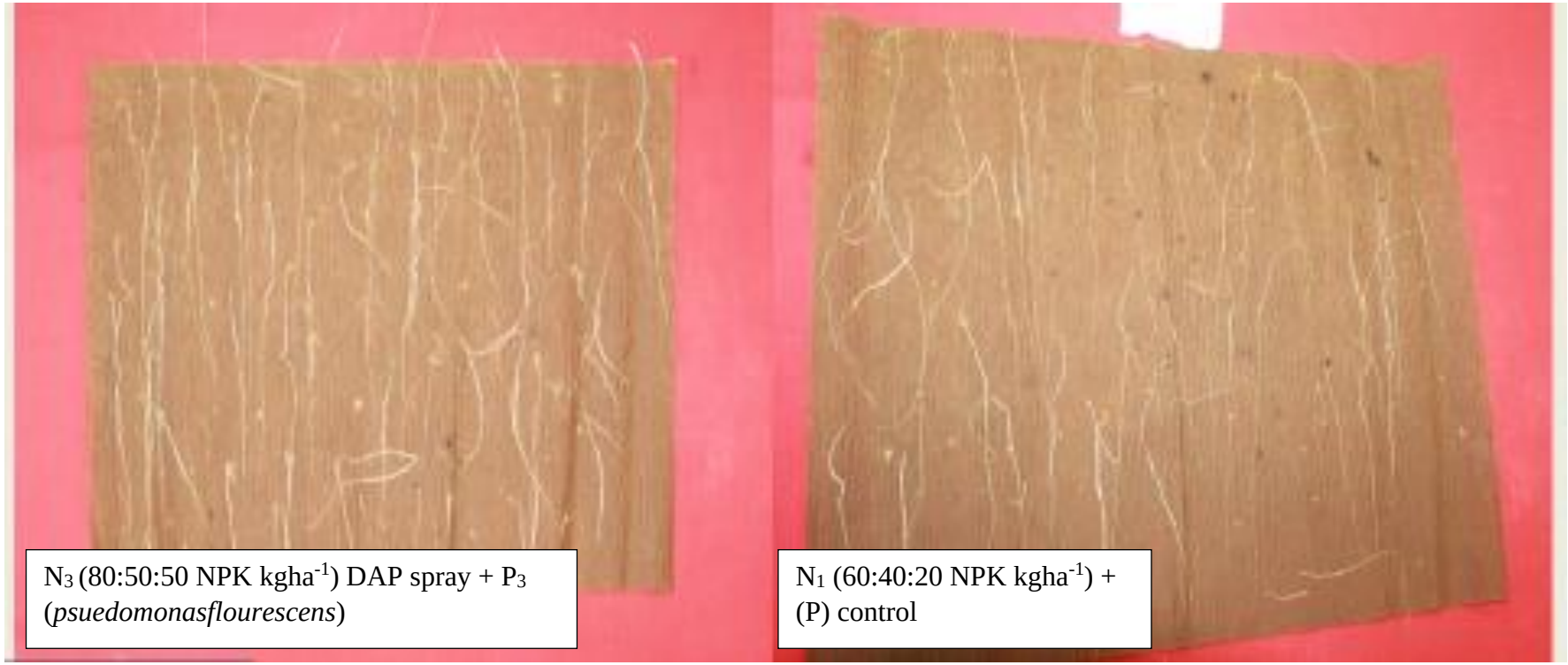

Plate 6: Influence of nutrient levels and seed bio-priming on seed germination

neem cake ha^{-1} + 1250 kg vermicompostha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+ 10 kg *Azospirillum* ha^{-1} (N_4).

Non-significant differences were observed in mean seedling length for different priming treatments. Among seed treatments, seed priming with *Pseudomonas fluorescens* (P_3) recorded maximum mean seedling length (11.48cm) and minimum mean seedling length (11.00 cm) was recorded under P_1(control).

Interactions had non-significant effect on the mean seedling length. Higher mean seedling length was recorded maximum in N_3P_3 (11.97 cm) while, least mean seedling length was recorded under N_1P_1 (10.67 cm).

The increase in root length and shoot length with primed seeds might be due to fact that, priming induces nuclear replication in root tips (Stofella *et al*., 1992). The maximum seedling length in seeds primed with *P. flueroroscens* might be attributed to enlarge embryos, higher rate of metabolic activities and respiration, better utilization and mobilization of metabolites to growing points and higher activity of enzymes. The results are in agreement with findings of Hussain et al. (1998) in tomato and Shahazad (2003) in wheat.

4.3.5 Mean seedling dry weight (mg)

The data pertaining mean seedling dry weight as influenced by nutrient levels priming treatments and their interaction are presented in table 4.7.

Different nutrient levels had a non-significant effect on mean seedling dry weight. The highest mean seedling dry weight (0.73 mg) was noticed under 80:50:50 NPK kg ha^{-1} +2 % DAP spray (N_3) and lowest (0.70 mg) was recorded under 60:40:20 NPK kg ha^{-1} (N_1)

Mean seedling dry weight had non-significant difference indifferent priming treatments. Among seed priming with *Pseudomonas fluorescens* (P_3) recorded maximum mean seedling dry weight (0.72 mg) and minimum mean seedling dry weight (0.71 mg) was recorded under P_1 (control).

Interactions had a non-significant effect on the mean seedling dry weight. Higher mean seedling dry weight was recorded maximum in N_3P_3 (0.73 mg) while, least mean seedling dry weight was recorded under N_1P_1 (0.688 mg).

4.3.6 Seedling vigour index- I

The results pertaining seedling vigour index-I as influenced by nutrient levels, priming treatments and their interaction are presented in table 4.7 and Fig 6.

Effect of different nutrient levels had a non-significant effect on seedling vigour index-I. The highest seedling vigour index (1007) was noticed under 80:50:50 NPK kg ha^{-1} + 2 %DAP spray (N_3)and lowest (924) was recorded under 125 kg neem cake ha^{-1} + 1250 kg vermicompost ha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+ 10 kg *Azospirillum* ha^{-1} (N_4).

Significant differences were observed for seedling vigour index-I due to different priming treatments. Among the seed priming treatment with *Pseudomonas fluorescens* (P_3) recorded maximum seedling vigour index-I (990) and minimum vigour index-I (932) was recorded under P_1 (control).

Interactions had a non-significant effect on the seedling vigour index. Higher seedling vigour index-I was recorded in N_3P_3 (1038) while, least seedling vigour index-I was recorded under N_4P_1 (896).

4.3.7 Seedling vigour index- II

The data pertaining seedling vigour index-II as influenced by nutrient levels priming treatments sand their interaction is presented in table 4.7 and Fig 7.

Different nutrient levels had significant effect on seedling vigour index-II. The highest seedling vigour index-II (632) was noticed under 80:50:50 NPK kg ha^{-1} + 2 % DAP spray (N_3) and lowest (588) was recorded under 60:40:20 NPK kg ha^{-1} (N_1).

Non-significant differences were observed for seedling vigour index for different priming treatments. Among seed priming with *Pseudomonas fluorescens* (P_3) recorded maximum seedling vigour index-II (616) and minimum vigour index-II (604) was recorded under P_1 (control).

Interactions had a non-significant effect on the seedling vigour index-II Higher seedling vigour index-II was recorded in N_3P_3 (639) while, least seedling vigour index-II was recorded under N_1P_1 (570).

4.3.8 Electrical conductivity (dS cm^{-1})

The data pertaining to electrical conductivity as influenced by nutrient levels and priming treatments and their interactions are depicted in the table 4.8.

Non-significant differences were observed for electrical conductivity due to different nutrient levels. The highest electrical conductivity (0.063 dS cm^{-1}) was recorded in 80:50:50 NPK kg ha^{-1}+ 2 % $FesSO_4$ spray (N_2) and lowest electrical conductivity (0.056) was recorded in 60:40:20 NPK kg ha^{-1} (N_1).

Influence of priming treatments differed non-significantly for electrical conductivity. The highest electrical conductivity (0.061 dS cm^{-1}) was recorded under P_1 (control) and lowest electrical conductivity (0.057 dS cm^{-1}) was recorded in *T. harzianum* (P_2).

Interaction effect of nutrient levels and priming treatments differed non-significantly for electrical conductivity. Among the interaction levels, the maximum electrical conductivity (0.063 dS cm^{-1}) was noticed in $N_3P_1$and minimum electrical conductivity (0.054 dS cm^{-1}) was recorded under N_4P_2.

4.3.9 Total dehydrogenase activity (A480)

The results pertaining to total dehydrogenase activity as influenced by nutrient levels and priming treatments and their interaction are presented in the table 4.8.

No marked differences were observed due to nutrient levels regarding total dehydrogenase activity. The highest total dehydrogenase activity (0.665) was observed for 80:50:50 NPK kg ha^{-1} + 2 % DAP spray (N_3) and lowest total dehydrogenase activity (0.547) was noticed in 60:40:20 NPK kg ha^{-1} (N_1).

Table 4.7 Influence of nutrient levels and seed bio priming on mean seedling length, mean seedling dry weight and seedling vigour index-I and II in quinoa cv. EC507740

Treatments	Mean seedling length (cm)	Mean seedling dry weight (mg seedling^{-1})	Seedling Vigour index I	Seedling Vigour index-II
Nutrient levels (N)				
N_1: 60:40:20 NPK kg ha^{-1}	11.17	0.70	943	588
N_2: 80:50:50 NPK kg ha^{-1} + 2 % $FeSO_4$ spray	11.23	0.72	960	622
N_3: 80: 50:50 NPK kg ha^{-1} + 2 % DAP spray	11.65	0.73	1007	632
N_4: 125 kg Neem cake ha^{-1}+ 1250 kg Vermicompost ha^{-1} + 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1} + 10 kg *Azospirillum* ha^{-1}	11.12	0.71	924	598
S.Em ±	0.28	0.09	26.38	10.5
CD (P = 0.05)	**NS**	**NS**	**NS**	3.09
Priming treatments (P)				
P_1 : Control	11.00	0.71	932	604
P_2: Seed priming with *Trichoderma rzianum*(1.5%)	11.41	0.71	985	611
P_3: Seed priming with (20 %) liquid *Pseudomonas fluorescens*	11.48	0.72	990	616
S.Em ±	0.25	0.07	22.84	0.91
CD (P = 0.05)	**NS**	**NS**	**NS**	**NS**
Interaction (NXP)				
N_1P_1	10.67	0.688	925	570
N_1P_2	11.55	0.707	985	599
N_1P_3	11.31	0.719	921	595
N_2P_1	11.08	0.719	919	615
N_2P_2	11.27	0.726	978	624
N_2P_3	11.36	0.727	985	629
N_3P_1	11.11	0.727	961	629
N_3P_2	11.88	0.731	1023	630
N_3P_3	11.97	0.735	1038	639
N_4P_1	11.14	0.724	925	603
N_4P_2	10.95	0.708	953	592
N_4P_3	11.29	0.708	896	601
S.Em ±	**0.50**	**0.01**	45.69	1.82
CD (P = 0.05)	**NS**	**NS**	**NS**	**NS**
CV (%)	**7.69**	**3.84**	8.25	5.19

NS- Non-Significant

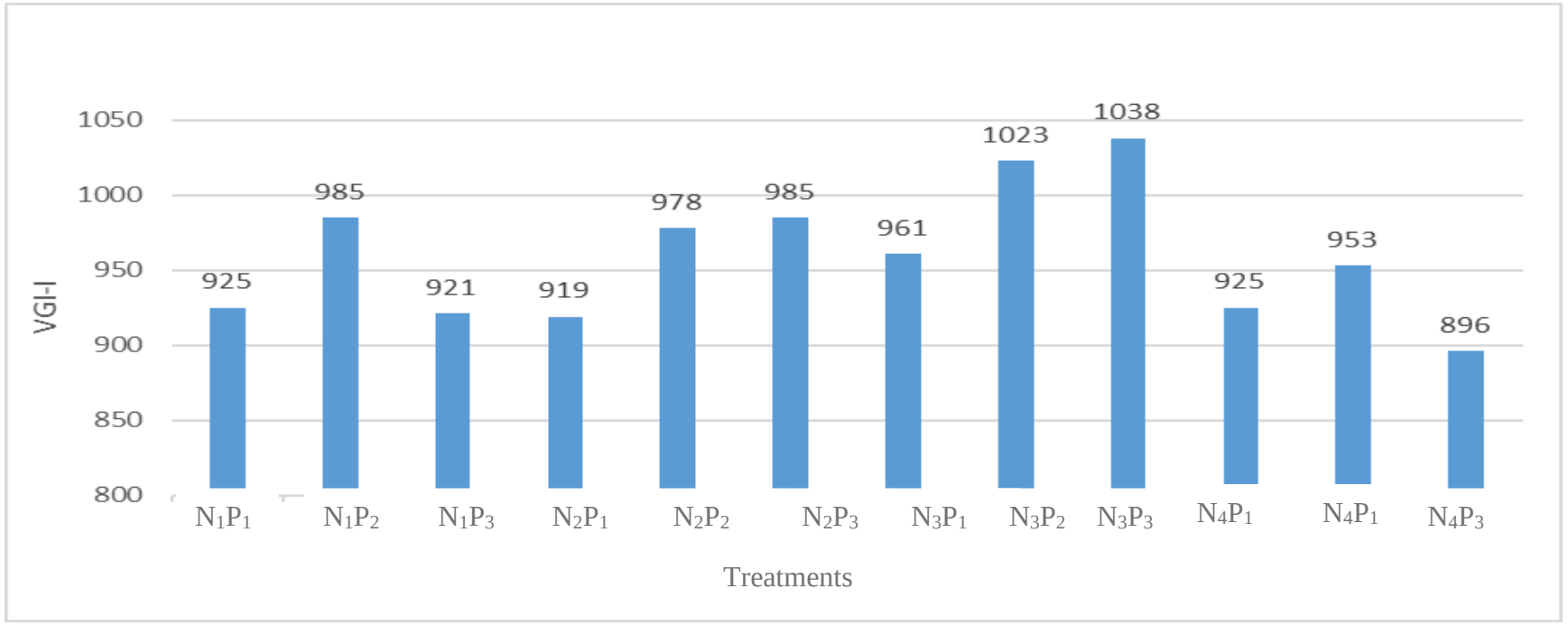

Fig. 6: Influence of nutrient levels and seed bio-priming on vigourindex-I

Treatment details:

I. Nutrient levels (N)

N_1 :60:40:20 NPK kg ha^{-1}

N_2 : 80: 50: 50 NPK kg ha^{-1}+2 % $Feso_4$ spray at flowering

N_3 : 80: 50: 50 NPK kg ha^{-1}+ 2 % DAP spray at pre-flowering

: 125 kg neem cake ha^{-1} + 1250 kg vermin compost ha^{-1}+ 10 kg PSB

N_4 ha^{-1} + 10 kg KSB ha^{-1}+10 kg *Azospirillum* ha^{-1}

II. Seed bio priming (P)

P_1 : Control

P_2 : Seed priming: with *T. harzianum* (1.5 %) (6hr)

P_3 : Seed priming with 20 % liquid *Pseudomonas fluorescence*(6 hr)

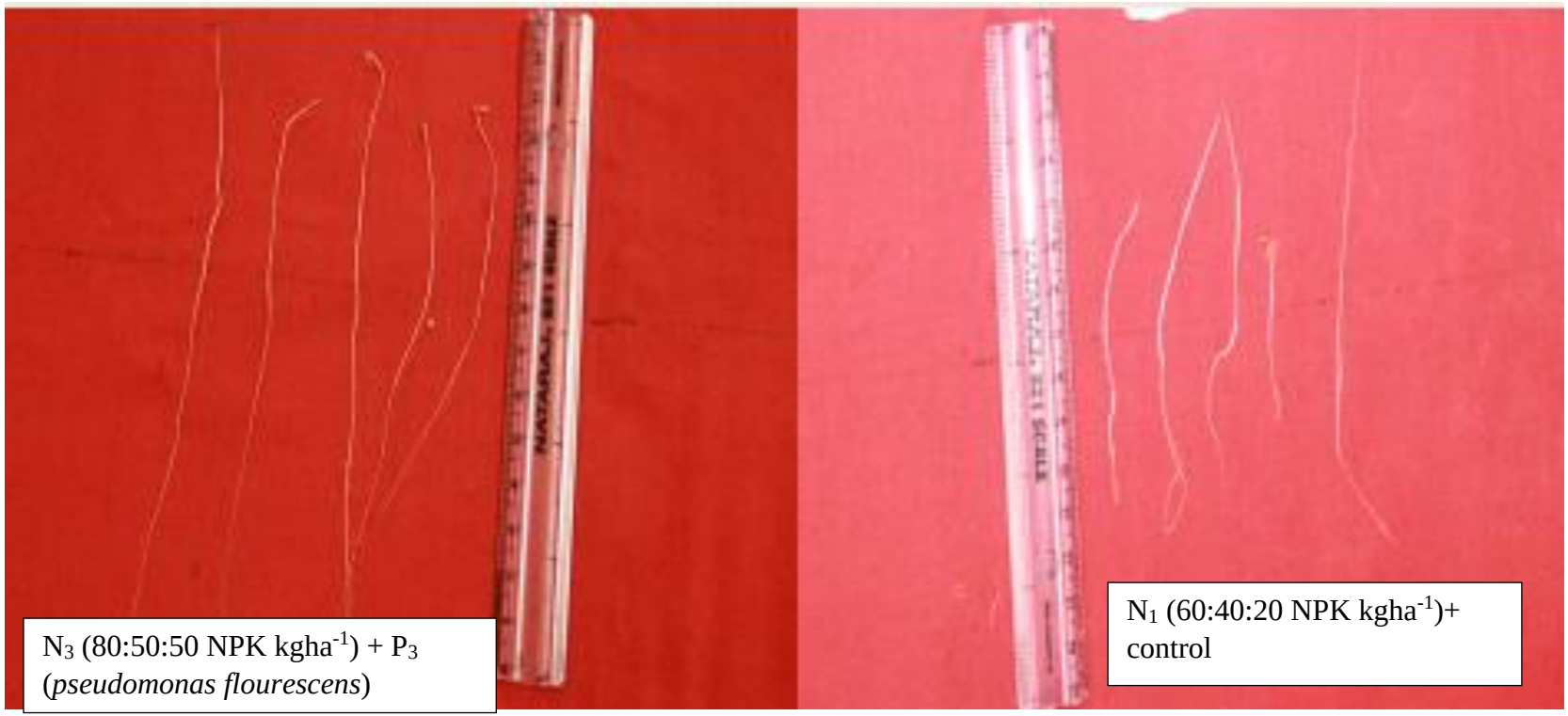

Plate 7: Influence of nutrient levels and seed bio-priming on mean seedling length of quiona

Non-significant difference was observed in total dehydrogenase activity due to different priming treatments. The maximum total dehydrogenase activity was recorded under seed priming with *Pseudomonas fluorescens* (P_3:0.629) and minimum total dehydrogenase activity was noticed under control, P_1 (0.545).

Interaction effect of nutrient levels and priming treatments differed non-significantly for total dehydrogenase activity. Among the interaction levels, N_3P_3 recorded highest total dehydrogenase activity (0.726) and N_4P_1 recorded lowest total dehydrogenase activity (0.301).

In the present investigation, it was observed that, among various nutrient management levels integrated use of 80:50:30 NPK kg^{-1} +2 % DAP spray during pre-flowering stage recorded significantly higher germination percentage (89.82%), mean seedling length (11.65 cm), mean seedling dry weight (0.731 mg), vigour Index-I (1007), vigour index-II (632). The present results also consist with the findings of Chintalapati sravani (2016).

The soil nitrogen balance has increase with increase in application of nitrogen through different form that might be attributed to the addition of more nitrogen during flowering stage and its slow release throughout the crop growth, which minimize the nitrogen loss. Accumulation of more food reserve mighthave increased seed germination, root length, shoot length, which turn resulted mean seedling length and seedling dry weight, (Muthuswamy *et al.*, 1990).

As fertilizer, level increased the seed vigour index also increased. This is mainly due to application of fertilizer dose enhances the accumulation of higher quantities of seed constituents like carbohydrates, proteins as enzymes which increased the seedling vigour index of bolder seeds with greater metabolites for resumption of embryonic growth during germination. Above results were in agreement with Anitha *et al*. (2015) in fenugreek.

In our findings increases in level of fertilizer increases the shoot length, root length and seedling length. This might be due to bolder seeds, having higher seed weight which contains greater metabolites for resumption of embryonic growth during germination and these metabolites release certain enzymes responsible for degradation of macromolecules into micro molecules within the seeds for increase of

seedling length. These evidences are supported by findings of Anitha *et al*. (2015) in sunflower crop reported that shoot length gradually increased with increase of nitrogen containing fertilizers.

Among three different priming treatments on quality parameters, seeds treated with *Pseudomonas fluorescens* (20 %) recorded significantly higher germination percentage (87.41 %), mean seedling length, mean seedling length (11.48 cm), dry weight (0.72 mg), vigour index-I (990), vigour index-II (616), dehydrogenase activity (0.629), electrical conductivity (6.79). These results are consisting with findings of Sridevi and Manonmani (2016). This might be the result of synergism of priming effect with bacterial effect since priming confers benefits such as completion or early germination phase, increasing the population of bio-protectants, rapid uniform seedling emergence, facilitation of uptake of water and nutrients, protection against pathogens, potential defense response such as early oxidation burst, incorporation of various phenolic compounds and polymers to the cell wall and secretion of phytoalexins according to Sridevi and Manomani (2016).

Among the various treatment tried in the study, integrated approach of inorganic fertilizers with 2 % DAP spray and seeds treated with *Pseudomonas fluorescens* increase plant growth, seed yield and quality parameters in quinoa variety under Bengaluru condition due to integrated synergistic effect of integrated approach

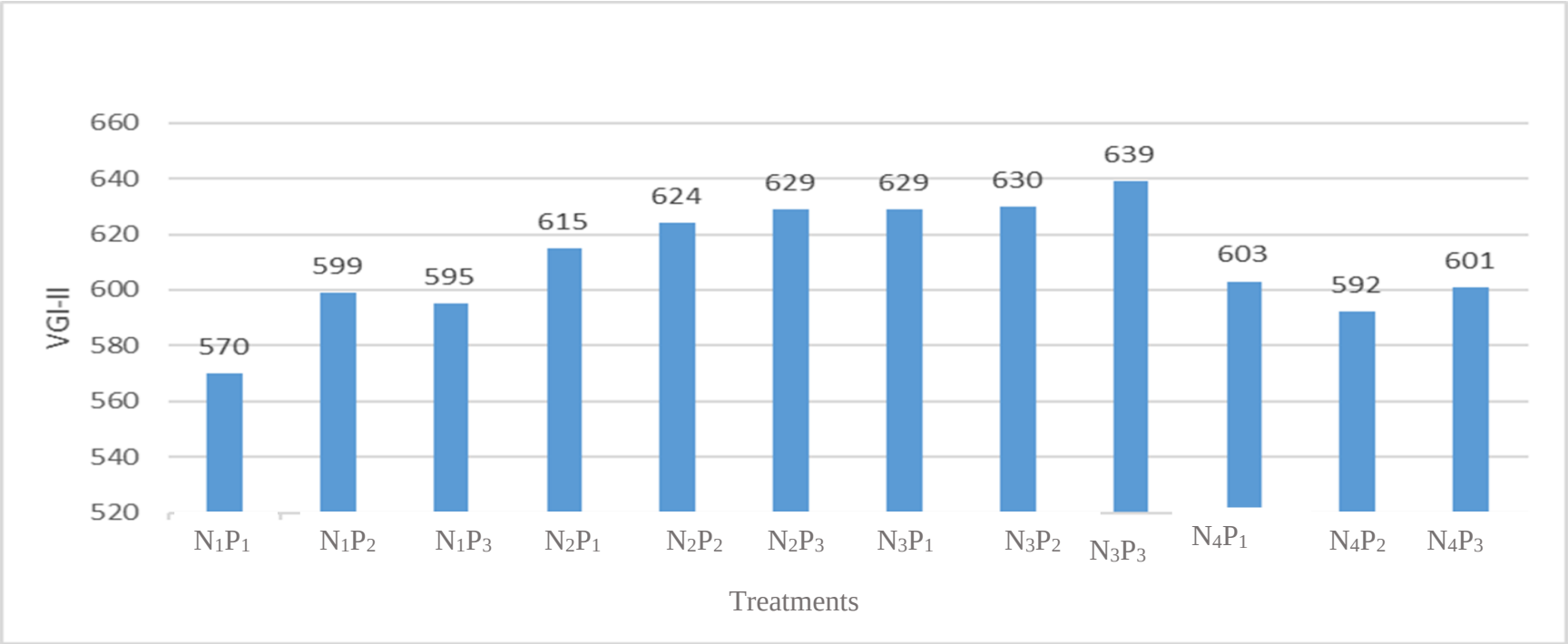

Fig. 7: Influence of nutrient levels and seed bio-priming on vigour index-II

Treatment details:

I. Nutrient levels (N)

N_1 :60:40:20 NPK kg ha^{-1}

N_2 : 80: 50: 50 NPK kg ha^{-1}+2 % $Feso_4$ spray at flowering

N_3 : 80: 50: 50 NPK kg ha^{-1}+ 2 % DAP spray at pre-flowering

N_4 : 125 kg neem cake ha^{-1} + 1250 kg vermin compost ha^{-1}+ 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1}+10 kg *Azospirillum* ha^{-1}

II. Seed bio priming (P)

P_1 : Control

P_2 : Seed priming: with *T. harzianum* (1.5 %) (6hr)

P_3 : Seed priming with 20 % liquid *Pseudomonas fluorescence*(6 hr)

Table 4.8 Influence of nutrient levels and seed bio priming on dehydrogenase activity, and electrical conductivity in quinoa *cv*. EC 507740

Treatments	Electrical conductivity (dS cm^{-1})	Dehydrogenase activity (A_{480} nm)
Nutrient levels (N)		
N_1: 60:40:20 NPK kg ha^{-1}	0.056	0.665
N_2: 80:50:50 NPK kg ha^{-1} + 2 % $FeSO_4$ spray	0.062	0.578
N_3: 80:50:50 NPK kg ha^{-1} + 2 % DAP spray	0.061	0.613
N_4: 125 kg Neem cake ha^{-1}+ 1250 kg Vermicompost ha^{-1} + 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1} + 10 kg *Azospirillum* ha^{-1}	0.063	0.547
S.Em ±	0.001	0.035
CD (P = 0.05)	**NS**	**NS**
Priming treatments (P)		
P_1 : Control	0.061	0.545
P_2: Seed priming with *Trichoderma harzianum* (1.5%)	0.057	0.628
P_3: Seed priming with (20 %) liquid *Pseudomonas fluorescens*	0.059	0.629
S.Em ±	0.001	0.03
CD (P = 0.05)	**NS**	**NS**
Interaction (NXP)		
N_1P_1	0.058	0.589
N_1P_2	0.056	0.711
N_1P_3	0.055	0.697
N_2P_1	0.063	0.630
N_2P_2	0.060	0.546
N_2P_3	0.062	0.559
N_3P_1	0.063	0.662
N_3P_2	0.059	0.642
N_3P_3	0.062	0.535
N_4P_1	0.060	0.301
N_4P_2	0.054	0.615
N_4P_3	0.059	0.726
S.Em ±	0.003	0.06
CD (P = 0.05)	**NS**	0.18
CV (%)	**8.83**	**17.77**

NS: Non-Significant

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4.4 Standardization of grading sieves for upgrade the seed quality

The important objective of seed processing with the use of appropriate sieves is to obtain maximum seed recovery with higher seed quality. For new varieties, it has become necessary for standardization for sieve which otherwise leads to the loss of seeds without considering their worth. The production conditions are such that, the seed produced will have varying size because of different climatic condition and differ in soil topography leads to varying in seed size. To avoid this loss and to improve the availability of seed material without scarifying the seed quality, it is necessary to find out sieves by studying the average size distribution and quality in the seed lots. The result of large scale processing of Quinoa seeds indicate that the highest seed recovery percentage was observed in 1.2 mm sieve (99.43 %) and lowest in 1.6 mm (84.49 %).

The studies on the quality parameters of the quinoa seeds revealed that in seed size had positive association with seed weight. The 1000 seed weight observed with different sieve size exhibited a reduction with reduction insieve size and 1.2 mm sieve recorded lowest 1000 seed weight (2.66 gm) but recovery percentage was higher i.e. 99.43 per cent. Debchoudhury *et al*. (1995) reported the positive association between size and weight of seed in rapeseed and Kumar *et al*. (2014) in Indian mustard.

Physical purity shows major difference between different sieve size, however highest physical purity percentage was recorded in sieve size 1.6 mm (99.68%) followed by 1.4 mm sieve (99.43 %). Similar observation of improved seed recovery and quality has been reported by Hanumantharaya (1991).

The parameters like 1000 seed weight, seed recovery, germination, vigor index, increased significantly with increase in sieve size from 1.2 mm to 1.6 mm. Highest germination (90.21%) was observed in 1.6 mm while, 1.2 mm sieve size recorded lowest germination percentage (88.20 %). However, seeds obtained from 1.4 mm sieve size meet the recommended germination with highest recovery. Higher and quick germination in bigger size seeds could be due to the presence of higher amount of carbohydrates and other nutrients than in small sized seeds. Similar observation also recorded in many tropical species Gunga *et al*. (2007). Highest germination percentage was observed in 1.6 mm although seeds obtained from 1.4 mm showed

lowest germination but it meets the minimum seed certification standard with highest seed germination percentage and highest physical purity.

Thus, study indicated that a sieve size of 1.4 mm can be considered optimum for processing quinoa seeds for more recovery (94.64 %) with seed quality parameter in acceptable limits of seed standards.

4.5 Practical utility

- The nutrient level at 80:50:50 NPKKg ha^{-1} +2 % DAP spray during flowering is found to be optimum and highest seed yield $plant^{-1}$ (6.97 g), seed yield $plot^{-1}$ (1.52 kg) and seed yield ha^{-1} (14.93q ha^{-1}) were recorded.
- Seeds bio-priming with (20 %) *Pseudomonas fluorescens* gives more seed yieldper plant (5.97 g), seed yield $plot^{-1}$ (1.35 g) and bulk seed yieldha^{-1} (14.21 q).
- Interaction of nutrient levels and seed bio-primingat N_3P_3 (80:50:50 Kg NPK ha^{-1}+ *Pseudomonas fluorescens* gave good quality seed.
- Graded seeds with 1.4 mm sieve is found optimum in higher seed recovery percentage (94.64 %), physical purity (99.43 %), germination (90.00 %) and 1000 seed weight (2.817 g).

4.6 Future line of work

- ✓ Studies on use of nano-nutrients and their effect could be initiated
- ✓ Seed bio-priming with other chemicals and botanicals can be assessed
- ✓ Standardization of harvesting techniques and procedures need to carried out
- ✓ Standardization of seed processing procedures can be studied
- ✓ Storage studies to standardize different chemicals, packaging materials could be studied

Table 4.9 Influence of seed size on seed quality in quinoa *cv*. EC 507740

Treatments	Recovery (%)	Physical purity (%)	Germination (%)	1000 seed weight (gm)	Mean seedling length (cm)	Mean seedling dry weight (gm)	Vigour index
S1 (1.2mm)	99.43	85.02	88.20	2.660	10.560	0.690	932
S2 (1.3mm)	98.33	88.81	88.96	2.750	11.340	0.737	1008
S3 (1.4mm)	94.64	99.43	90.00	2.817	11.743	0.743	1056
S4 (1.6mm)	84.49	99.68	90.21	3.067	11.523	0.730	1039
SE.m ±	0.34	0.27	0.30	0.0243	0.1320	0.0085	11.49
CD@1 %	1.64	1.29	1.46	0.11	0.62	0.04	54.52

V SUMMARY

An investigation pertaining to "Influence of nutrient management and seed bio-priming on seed yield and quality in Quinoa (*Chenopodium quinoa* Willd.)" conducted during Rabi 2019-20 at ICAR- Indian Institute of Seed Science MAU, Regional station, UAS, GKVK, Bengaluru. The experiment was laid out in FRCBD design with twelve treatment combinations in three replications.

The present study was undertaken with the objective to: To assess the effect of nutrient management on seed yield and quality. To evaluate the seed bio-priming techniques on seed yield and quality. The attempt was also made to standardize the grading sieves for up-gradation of seed quality.

5.1Growth parameters affected by nutrient levels

Nutrient application of 80:50:50 NPK kg ha^{-1} + (2 %) DAP spray during flowering recorded highest plant height at 30 DAS (33.8 cm), 60 DAS (88.72 cm), at harvest (90.47 cm), total number of panicles $plant^{-1}$ (12.25), panicle length of main stem (30.05 cm), panicle dry weight $plant^{-1}$ (25.31 g), seed yield $plant^{-1}$(6.49 g), seed yield $plot^{-1}$ (1.44 kg), seed yield ha^{-1} (14.47 q ha^{-1}) total number of branches $plant^{-1}$ (12.95), and lower values are noted in nutrient application of 60:40:20 NPK kg ha^{-1}(27.11cm, 84.46cm, 84.30cm, 9.42, 27.57 cm, 20.15 g, 4.53 g, 1.32 kg, 12.37 q ha^{-1} respectively) and nutrient application 125 kg ha^{-1} neem cake + 1250 kg ha^{-1} vermicompost + 10 kg PSB ha^{-1} + 10 kg KSB ha^{-1} + 10 kg *Azospirillum* $ha^{-1}$of recorded more number of days for 50 per cent flowering (42.22 days) and days taken to maturity (92.33).

5.2 Growth and yield parameters affected by priming treatments

Priming treatments of (P_3) *Pseudomonas fluorescens* (20 %) recorded highest plant height at 30 DAS (33.45 cm), plant height at 60 DAS (85.58), plant height at harvest (90.05),total number of panicles $plant^{-1}$ (11.53) ,panicle length of main stem (28.34 cm), panicle dry weight $plant^{-1}$ (23.65 g), seed yield $plant^{-1}$ (5.97 g), seed yield ha^{-1}(14.21 q ha^{-1}), total number of branches $plant^{-1}$ (12.01), control seeds taken more number of days for flowering days to 50 % flowering (41.66 days) and days taken to maturity (92.08 days) and lower values are noted in lower nutrient application (P_1)

control seeds (28.07 cm, 84.14 cm, 86.47 cm, 10.06, 28.41 cm, 21.73 g, 5.41 g, 13.38 q ha^{-1}, 11.16, respectively).

5.3 Growth and yield parameters affected by interaction of nutrient levels and priming treatments

Nutrient treatment 80:50:50 NPK kg ha^{-1}+ (2 %) DAP spray and seeds treated with *Pseudomonas fluorescens* (N_3P_3) recorded higher plant height at 30 DAS (36.10 cm), 60 DAS (88.83 cm), at harvest (91.80 cm), total number of panicles $plant^{-1}$ (13.10),panicle length of main stem (32.57 cm), panicle dry weight $plant^{-1}$ (27.13 g), seed yield $plant^{-1}$ (6.97 g), seed yield $plot^{-1}$ (1.52 kg), seed yield ha^{-1} (14.93 q ha^{-1}), and lower values are noted in N_1P_1 (27.11 cm, 84.46 cm, 87.73 cm, 9.67, 24.93, 14.80 g, 1.32, 11.38 q ha^{-1}, respectively).

5.4 Seed quality parameters affected by nutrient levels

Nutrient application of 80:50:50 NPK kg h^{-1} + (2 %) DAP spray recorded gave higher results test weight (2.91 g), germination (89.82 %), mean seedling length (11.65 cm), mean seedling dry weight (0.731 mg), seedling vigour index- I (1007), seedling vigour index- II (632), total dehydrogenase activity (0.613 A_{480} nm), and lower values are noted in $N_1$80:50:50 NPK kg ha^{-1} recorded lower values as follows (2.91 g, 84.49%, 11.17 cm, 0.70 mg, 943 respectively).

5.5 Seed quality parameters affected by priming levels.

Priming treatments of (P_3) *pseudomonas fluorescens* (20 %) differed non significantly and gave results like test weight (2.87 g), germination (87.41 %) mean seedling length (11.48 cm), mean seedling dry weight (0.72 mg), seedling vigour index- I (990), seedling vigour index- II (616), electrical conductivity (629 ds cm^{-1}), whereas lower values were recorded in P1(control seeds: 2.82 g, 86.26 %, 11.00 cm, 0.71 mg, 932, 604, respectively).

5.6 Seed quality parameters affected by interaction of nutrient levels and priming treatments

Nutrient treatment 80:50:50 NPK kg ha^{-1}+ 2 % DAP spray with seeds treated with *pseudomonas fluorescens* (N_3P_3) recorded test weight (2.99 g), germination

90.50 % mean seedling length (11.97 cm), mean seedling dry weight (0.735 mg), seedling vigour index- I (1038), seedling vigour index- II (639), electrical conductivity (0.062 dS cm^{-1}), dehydrogenase activity (0.535 A_{480} nm), whereas lower values recorded in N_1P_1 as follows (2.83 g, 82.83 %, 10.67 cm, 0.688 mg, 925, 570, respectively).

5.7 Influence of seed size on seed quality in quinoa.

Seed size had positive association with seed weight. The 1000 seed weight observed with different sieve size exhibited a reduction with reduction in size 1.2 mm sieve recorded lowest 1000 seed weight (2.66 gm) but recovery percentage was higher i.e. 99.43. The positive association between size and weight of seed.

Physical purity shows major difference between different sieve size, however highest physical purity percentage was recorded in sieve size 1.6 mm (99.68 %) followed by 1.4 mm sieve (99.43 %). The parameters like 1000 seed weight, seed recovery, germination, mean seedling length, vigour index increased significantly with increase in sieve size from 1.2 mm to 1.6 mm. Highest germination percentage (90.21 %) was observed in 1.6 mm while 1.2 mm sieve size recorded lowest germination percentage (88.20 %). However, seeds obtained from 1.4 mm sieve size meet the recommended germination percentage with highest recovery percentage. Highest germination percentage was observed in 1.6 mm although seeds obtained from 1.4 mm showed lowest germination but it meet the minimum seed certification standard with highest seed germination percentage and highest physical purity. Thus study indicated that, a sieve size of 1.4 mm can be considered optimum for processing quinoa seeds for more recovery (94.64 %) with seed quality parameter in acceptable limits of seed standards.

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APPENDIX- I

Physical and chemical properties of the soil (initial data) at the experimental site.

Sl. No.	Particulars of analysis	Values	Method adopted
I	**Physical properties**		
1	Sand (%)	46.30	International pipette method (Piper. 1966)
2	Silt (%)	19.60	
3	Clay (%)	34.10	
4	Bulk density (g cc^{-1})	1.28	Core Sampler Method (Black, 1967)
II	**Chemical properties**		
1	pH (1:2.5)	7.5	pH meter method (Jackson, 1973)
2	Electrical conductivity (d S m^{-1})	0.322	Conductivity bridge (Jackson, 1973)
3	Organic carbon (g kg^{-1})	0.41	Wet oxidation method (Black, 1967)
4	Available nitrogen (kg ha^{-1})	143.46	Alkaline permanganate method (Subbiah and Asija, 1956)
5	Available phosphorus (kg ha^{-1})	27.16	Olsen's method (Jackson, 1973)
6	Available potassium (kg ha^{-1})	374.16	Flame photometry (Jackson, 1973)
7	Available sulphur (kg ha^{-1})	26.94	Spectrophotometer (Jackson, 1973)
8	Ex. Calcium (C mol (p^{+}) kg^{-1})	28.8	Determined in neutral normal ammonium acetate leachate as described by Black (1965)
9	Ex. Magnesium (C mol (p^{+}) kg^{-1})	7.2	
10	Available iron (mg kg^{-1})	3.18	Atomic absorption spectrophotometer method (Lindsay and Norvell, 1978)
11	Available copper (mg kg^{-1})	5.87	
12	Available manganese (mg kg^{-1})	8.76	
13	Available zinc (mg kg^{-1})	0.73	

APPENDIX-II

Mean monthly meteorological data from January to December 2019 at NSP, GKVK

Month	Rainfall (mm)			Mean temperature (°C)						Mean relative humidity (%)		
				Maximum			Minimum					
	N	A	D	N	A	D	N	A	D	N	A	D
January	1.4	0.00	-1.4	27.4	27.9	0.5	14.0	13.1	-0.9	86	87	1
February	8.6	24.00	15.4	30.0	30.6	0.6	15.4	15.3	-0.1	81	86	5
March	16.5	0.00	-16.5	32.7	33.7	1	18.0	17.7	-0.3	76	78	2
April	46.1	22.60	-23.5	33.8	34.7	0.9	20.5	20.8	0.3	79	83	4
May	104.1	126.40	22.3	33.0	33.7	0.7	20.5	20.1	-0.4	82	86	4
June	80.4	89.20	8.8	29.5	30.6	1.1	19.5	19.7	0.2	86	90	4
July	103.3	34.20	-69.1	28.2	29.5	1.3	19.1	19.5	0.4	89	92	3
August	129.7	173.40	43.7	27.7	27.5	-0.2	18.9	18.8	-0.1	90	94	4
September	196.0	186.60	-9.4	28.1	27.9	-0.2	18.9	19.2	0.3	89	92	3
November	56.2	10.00	-46.2	26.7	27.6	0.9	16.6	16.9	0.3	87	89	2

Note: N- Normal meteorological data (mean of 1976-2017), **A** - Actual meteorological data, **D** - Deviation from the normal (A-N)