Biological Forum – An International Journal **15(2): 1251-1258(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Assessment of Effect of Beneficial Microorganisms on Plant Growth and Yield of Quinoa (*Chenopodium quinoa* Wild) under Semi-arid Alfisols

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(Received: 06 January 2023; Revised: 17 February 2023; Accepted: 21 February 2023; Published: 23 February 2023)
(Published by Research Trend)

ABSTRACT: The University of Agricultural Sciences, Bangalore, undertook an experiment to determine the impact of advantageous microbial inoculants on the growth and yield of quinoa in glass house conditions. Five microbiological cultures were examined: *Glomus fasciculatum*, *Bacillus megaterium*, *Fraturia aurantia*, *Pseudomonas fluorescens*, and *Azotobacter chroococcum*. Pure cultures of chosen isolates of *Bacillus megaterium*, *Fraturia aurantia*, *Azotobacter chroococcum*, and *Pseudomonas fluorescens* were sub-cultured on a particular medium and kept in slants for further research. To find the best treatment for achieving the highest plant growth and yield characteristics, 17 treatments were examined. According to the Analysis of Variance, there were substantial differences between treatments in how they affected plant characteristics and quinoa yield. T17 seeded with *Azotobacter chroococcum* + *Bacillus megaterium*+ *Pseudomonas fluorescens* was superior with considerably higher plant height, number of leaves per plant, number of branches per plant, leaf area, length and weight of the panicle, weight of the shoot and root, and quinoa grain yield. The number of leaves per plant and the number of branches per plant both showed statistically significant associations with plant height. Plant height, the number of leaves, and the number of branches per plant were all substantially linked with panicle length and weight. Significant correlations existed between panicle length, weight, shoot and root dry weight, and leaf area. Plant height, leaf count, panicle length, panicle weight, shoot and root dry weight, leaf area, and soil N all had a substantial impact on quinoa yield. To achieve the best plant development and yield metrics, we advise using T17 inoculated with *Azotobacter chroococcum* + *Bacillus megaterium* + *Pseudomonas fluorescens*. A requirement for Before being widely used by farmers in semi-arid Alfisols, the superior microorganisms must be tested in the field for greater efficacy.

Keywords: Microbial cultures, Plant growth traits, Yield parameters, Correlation, Alfisols

INTRODUCTION

Latin American Andean mountains are known for its principal food crop, quinoa (*Chenopodium quinoa* Wild), sometimes known as the "golden grain." The Andean region's inhabitants protected it for thousands of years, and only lately did the rest of the world learn about it. It is distinguished by exceptional protein quality and high levels of a variety of vitamins and minerals. It was chosen by FAO as one of the crops destined to provide food security in the twenty-first century for this reason. Bread, soups, salads, breakfast, etc. all use quinoa. Quinoa is used in industry to make starch, protein, colourants, and saponin. Increased quinoa consumption in the West and Asia will boost domestic and urban markets in quinoa-producing nations. Depending on the variety, cool regions with temperature swings between -4°C at night and close to 35°C during the day would provide the best growing conditions. It is necessary to receive 300–1000 mm of rain during the growing season, but not at the time of seed development or harvest. The ideal soil conditions for quinoa growth are sandy, well-drained, low in nutrients, moderately salt, and pH 6.0–8.5. To prevent water logging, the seed bed must be properly prepared and drained. NPK would be needed for quinoa at 120:50:50 kg/ha.

According to the FAO, quinoa grain is the only vegetable food that, in levels comparable to milk, offers all of the required amino acids for human life. Lycine, isoleucine, methionine, histidine, cystine, and glycine are highly

concentrated in quinoa's protein composition, which ranges from 7.47 to 22.08%. Quinoa has a 3.4% ash level and is rich in calcium, iron, zinc, copper, and manganese. The oil content ranges from 1.8 to 9.5% and is high in linoleate and linolenate, two important fatty acids. Thiamine (0.4 mg), folic acid (78.1 mg), vitamin C (16.4 mg), riboflavin (0.39 mg), and carotene (0.39 mg) are all abundant in 100 g of quinoa seed. The calorific value is about 350 cal/100 g grain, which is more than that of other cereal and legume foods. It contains natural anti-oxidants like α-tocopheral (5.3 mg), γ-tocopheral (2.6 mg) in 100 g seed and phytoestrogens which prevent chronic diseases like osteoporosis, breast cancer, heart diseases and other feminine problems caused by lack of oestrogen during menopause (Bhargava *et al*., 2006).

Azotobacter chroococcum. *Azotobacter chroococcum*, a Gram negative bacterium belongs to family *Azotobacteraceae* of proteobacteria is a coherent group of aerobic, free living diazotrophs able to fix atmospheric N in N free or N poor medium with organic carbon compounds as energy source. Several properties of *Azotobacter* are responsible for beneficial effects on associated plants. Brown and Burlingham (1968) reported that use of starch as a selective medium for isolating *Azotobacter* and proved other media for isolation of this organism on Waksman No.77, Ashby's mannitol phosphate agar medium, Jensen's medium and Burk's N free medium.

Bacillus megaterium. The genus *Bacillus* are heterogenic group of Gram positive rods, able to form endospores that would allow them to survive for extended periods under adverse environmental conditions. Heekyung *et al.* (2005) studied bacterial groups which actively solubilize phosphates from soil rhizosphere of various crops. Anita *et al.* (2006) reported morphological, physiological and biochemical characteristics of phosphate solubilizing bacterial strain, which were isolated from a sub-alpine Himalayan forest site. After 15 days of incubation, the maximum amount of phosphate solubilization activity was noted at 21°C. Several rhizobacteria would boost the availability of P to plants by either mineralizing organic phosphate or solubilizing inorganic phosphate by producing acids (Rodriguez and Fraga 1999).

Fraturia aurantia. *Fraturia aurantia* is the potassium solubilizing bacteria which helps in the availability of potassium to plants. Potential of P and K solubilizing bacteria studied in egg plants, amendment of its respective P or K material increased P and K availability in soil (Han and Lee 2005). K nutrient's effects on native bacteria that solubilize it showed a significant enhancement in yield and plant uptake and were retained in the soil along with other quality measures in a tea plantation (Bagyalakshmi *et al*., 2012).

Pseudomonas fluorescens. Plant growth promoting rhizo microorganisms have shown diversity in their existence. They are free-living, colonizing/endophytic in nature and perform an important role in disease control and plant growth promotion. Among different PGPRs, fluorescent *Pseudomonas* emerged as largest and potentially most promising group of PGPR with rapid growth, simple nutritional requirement, ability to utilize diverse organic substrates and mobility. Heidari *et al.* (2011) reported that *Pseudomonas flourescens* (UTPF-61) isolated from rice rhizosphere acts as a bio-control agent against *sclerotia* wilt of sunflower, an important disease caused by *Sclerotinia sclerotiorum*. Rakh *et al.* (2011) investigated effect of *Pseudomonas* isolates as PGPR in groundnut and as a bio-control agent against *Sclerotium rolfsii* in a pot culture study. Bio-control agent treated plants indicated a vigorous growth and no disease incidence.

Mychorrhizae. Mycorrhiza, which means 'fungus root' was first described by German Forest Pathologist A.B. Frank in 1885. Since then, it is recorded on a vast majority of terrestrial plants. A vital connection between the plant, root, and soil is created by the symbiosis' bidirectional transport of nutrients, which moves carbon to the fungus and inorganic nutrients to the plant (Gerdemann, 1968). Mycorrhizal fungi would lessen transplant damage, improve plant water transpiration, and are salt-resistant (Menge *et al.,* 1978). Arbuscular Mycorrhizal Fungi (AMF) produces harmones, promotes establishment of plants in waste lands and mine soils.

Interaction effect of Azotobacter, PSB and VAM. Azcon and Barea (1996) studied effect of free living microorganisms viz., bacterium and fungus, along with *G. fasciculatum* and *Glomus mosseae* on development of *Medicago sativa.* The study revealed about better establishment of *G. fasciculatum* and *Glomus mosseae* along with other organisms. Application of microbial inoculant like AMF and PGPR such as *Azospirillum, Pseudomonas*, *Rhizobium* and several Gram positive *Bacillus* species are ecofriendly, energy efficient and economically viable for increasing biomass production and reclamation of wastelands (Tain *et al.,* 2004; Domenech *et al.,* 2004; Rabie and Almadini 2005). Poinkar *et al*. (2006) observed that application of FYM (10 t ha^{-1})+*Azotobacter*+PSB (250 g/10 kg seed) significantly increased number of leaves, plant height, size and surface area of leaves, girth of pseudostem, number of tillers/plant and fresh yield in turmeric.

MATERIALS AND METHODS

Experimental details. Mycorrhizal fungi would lessen transplant damage, improve plant water transpiration, and are salt-resistant. The University of Agricultural Sciences (UAS), Bangalore, carried out a research study with the aim of examining the impact of advantageous microorganisms on the growth and yield of quinoa in greenhouse conditions. The study used free-living N fixer, P solubilizer, and K solubilizer that had been collected, purified, mass-produced, and then formed.

The study's several microbiological cultures include (i) *Azotobacter chroococcum* (ii) *Bacillus megaterium* (iii) *Frateuria aurantia* (iv) *Pseudomonas fluorescens* and (v) *Glomus fasciculatum.* These cultures were obtained from Department of Agricultural Microbiology, UAS, Bangalore. The 24-hour old pure cultures of (i) *Azotobacter chroococcum* (ii) *Bacillus megaterium* (iii) *Pseudomonas fluorescens* and (iv) *Fraturia aurantia* were inoculated aseptically into flasks containing (i) Waksmann No.77 broth (ii) Sperber's broth (iii) King's B broth and (iv) Aleksandrow broth medium respectively with the help of inoculation loop and were incubated on a mechanical shaker for 3 days for growth. *Azotobacter chroococcum* was grown on Waksman No.77 medium, while *Bacillus megaterium* was grown on Sperber's medium. Similarly, *Pseudomonas fluorescens* was grown on king's B medium, while *Frateuria aurantia* was grown on Aleksandrow Agar medium (Ameer Pasha, 2019). Pure cultures of *Azotobacter chroococcum*, *Bacillus megaterium, Fraturia aurantia* and *Pseudomonas fluorescens* isolates were sub-cultured on the specific medium *viz.,* Waksman No.77, Pikovskaya's agar medium, Aleksandrow Agar, and king's B medium respectively and were maintained in the slants for future study.

The experiment was conducted with the objective of studying effect of selected microbial inoculants on growth and yield of quinoa under greenhouse condition with 17 treatments and each with 3 replications. While preparing the poting substrate, red sandy loam soil was collected from an uncultivated field in UAS, Bengaluru and used as planting medium. The soil was sieved with a 4 mm sieve and mixed thoroughly in order to get a homogenous mixture. The pots were filled with well homogenised pot mixture of soil: sand: FYM in 2:1:1 ratio @ 10 kg/pot.

Soil chemical properties. Soil samples were analyzed for soil reaction (pH), electrical conductivity (EC), organic carbon (OC), nitrogen (N), phosphorus (P) and potassium (K) by standard procedures. Soil reaction (pH) was determined in 1:2.5 soil water suspension by Potentiometric method using digital pH meter (Piper, 1966). Electrical conductivity (dS m^{-1}) was determined in 1:2.5 soil water extract using conductivity bridge (Jackson, 1973). Soil organic carbon was determined by using wet oxidation method (Piper, 1966). A known weight of soil was treated with excess volume of potassium dichromate solution in the presence of concentrated H_2SO_4. The organic carbon available in soil was oxidized to carbon dioxide (CO_2). Excess of potassium dichromate that was unused was titrated back against ferrous ammonium sulphate in the presence of concentrated phosphoric acid and diphenyl amine indicator.

Estimation of available N in soil was made by using alkaline potassium permanganate method (Subbaiah and Asija 1956). The soil of 0.5 g was treated with an excess of alkaline 0.32% potassium permanganate (made alkaline with 25% NaOH solution). The liberated ammonia was trapped in boric acid and was determined by titration against standard H_2SO_4. Available N (kg/ha) was computed using the titer value. Available P (kg/ha) of soil was estimated by using Brays-1 reagent. The extracted P was estimated by ascorbic acid method. Intensity of blue colour was measured using Spectrophotometer at 660 nm as described by Jackson (1973). Soil K was extracted from air-dried samples by shaking with 0.5M ammonium acetate/acetic acid solution for 30 minutes. This effectively displaced potentially available K+ ions. K content of filtered extract was determined using Flame Photometer (Jackson, 1973). Based on the initial soil analysis, the soil used in the study had pH of 6.6, electrical conductivity of 0.24 dS m^{-1}, organic carbon of 0.56%, available N of 342 kg/ha, P of 38.21 kg/ha and K of 234.5 kg/ha.

Treatment imposition/inoculation. Separately combined with a carrier (talc), the microbial inoculants of the broth cultures of *Azotobacter chroococcum*, *Bacillus megaterium*, *Fraturia aurantia*, and *Pseudomonas fluorescens* were left at room temperature for a week to stabilise. Just prior to planting, each carrier-based inoculant was administered to each pot with around 10 g. Three replications of observations on plant parameters were made during harvest. Before planting a crop, a seed germination (%) test using the papper towel method was carried out in a lab setting. For the provided seeds, germination rates of about 90% were seen. At the time of crop harvest, the plant's height (in cm), number of leaves per plant, and number of branches per plant were noted. Plant height was measured from ground level to tip of top most leaf of plant. Number of primary, secondary and tertiary branches/plant were counted at harvest of crop. Leaf area was measured for single plant using LI-3000 Portable Area Meter (LICOR model) with transparent conveyor belt utilizing an electronic digital display. Excised leaves were fed into the conveyor belt assembly, and leaf area was displayed digitally in cm^2.

Statistical analysis. The data were subjected to Analysis of Variance (ANOVA) in order to compare the effects of the various treatments. The significance of differences between treatments was assessed using Duncan's Multiple Range Test (DMRT). Different parameters were used to rate the treatments, and the best treatments were found. To evaluate the significance of parameters for describing the variability in data, estimates of correlation between various parameters were calculated. Regression coefficients were used to determine the contributions of plant features to yield for the variables plant height, number of leaves per plant, number of branches per plant, leaf area, shoot dry weight, root dry weight, panicle length, and panicle weight. Based on coefficient of determination (R2) measurements for each

model, regression models of yield through several plant attributes were assessed (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Effect of microbial inoculants on plant height. Based on ANOVA, treatments were significantly different in influencing the plant height at p< 0.05 level of significance. The plant height ranged from 100.30-118.97 cm with mean of 110.23 cm (CV of 5.0%). Significantly higher plant height of 118.97 cm was attained by T17 inoculated with *Azotobacter chroococcum+ Bacillus megaterium+Pseudomonas fluorescens*, followed by T16 inoculated with *Frateuria aurantia+ Pseudomonas fluorescens* with plant height of 116.30 cm (Table 1). Lowest plant height was observed in control (T1). Based on DMRT, T17 was superior compared to other treatments for attaining maximum plant height. The increase (%) of treatments over control ranged from 1.3-15.7% with mean of 9.3% (CV of 44.9%). This was due to rapid multiplication of microorganisms applied to soil in T17, which lead to significant positive effect on plant growth due to soil and plant microbe interactions. The increase in plant height could be attributed to sufficient availability and transportation of nutrients due to effective functioning of microbial inoculants. Similar effects were found through synthesis and exudation of plant growth promoting substances like IAA and GA (Tien *et al.*, 1979).

Effect of microbial inoculants on number of leaves/plant. Based on ANOVA, treatments were significantly different in influencing the number of leaves/plant at p<0.05 level of significance. The number of leaves/plant ranged from 159.58-243.51/plant with mean of 207.74/plant (CV of 10.6%). Significantly higher number of leaves/plant of 243.51 was recorded in T17 inoculated with *Azotobacter chroococcum+Bacillus megaterium+Pseudomonas fluorescens*, followed by T16 which received only *Frateuria aurantia+Pseudomonas fluorescens* with 235.65 leaves/plant (Table 1). Lowest number of leaves/plant was recorded in control. Based on DMRT, T17 was superior compared to other treatments for attaining maximum number of leaves/plant. The increase (%) of a treatment over control ranged 12.5-34.5% with mean of 23.7% (CV 28.9%).

Effect of microbial inoculants on number of branches/plant. Based on ANOVA, treatments were significantly different in influencing the number of branches/plant at p<0.05 level of significance. The number of branches/plant ranged from 29.24-45.89 with mean of 37.64 (CV of 13.1%). Significantly higher number of branches/plant of 45.89 was attained by T17 inoculated with *Azotobacter chroococcum+Bacillus megaterium+Pseudomonas fluorescens*, followed by T16 which received *Frateuria aurantia+Pseudomonas fluorescens* with 43.61 branches/plant. Lowest number of branches/plant was observed in the control. Based on DMRT, T17 was superior compared to all other treatments for attaining significantly higher number of branches/plant at harvest. T17 which received *Azotobacter chroococcum+Bacillus megaterium+ Pseudomonas fluorescens* was superior with significantly higher plant height, number of leaves/plant and number of branches/plant compared to other treatments (Table 1). The increase (%) of a treatment over control ranged from 4.3-36.3% with mean of 22.3% (CV of 44.4%). The number of branches and leaves/plant might have increased due to increased availability of N and P nutrients, and production of growth promoting substances by microbial inoculants. Similar results were reported by Gholani *et al.* (2009). They observed that phospho-bacteria solubilize and increase P availability to the plants and enhance plant uptake. Our results are in confirmation with the findings of Raj *et al.* (2004).

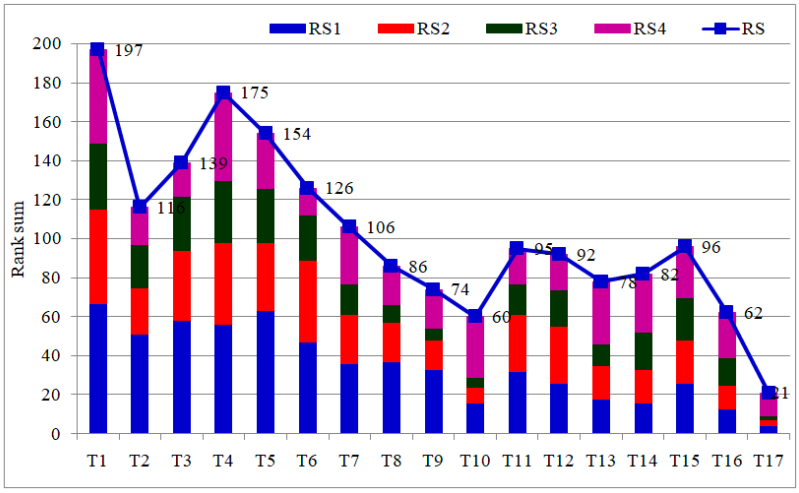

Fig. 1. Rank sum of treatments for different plant traits and yield of quinoa.

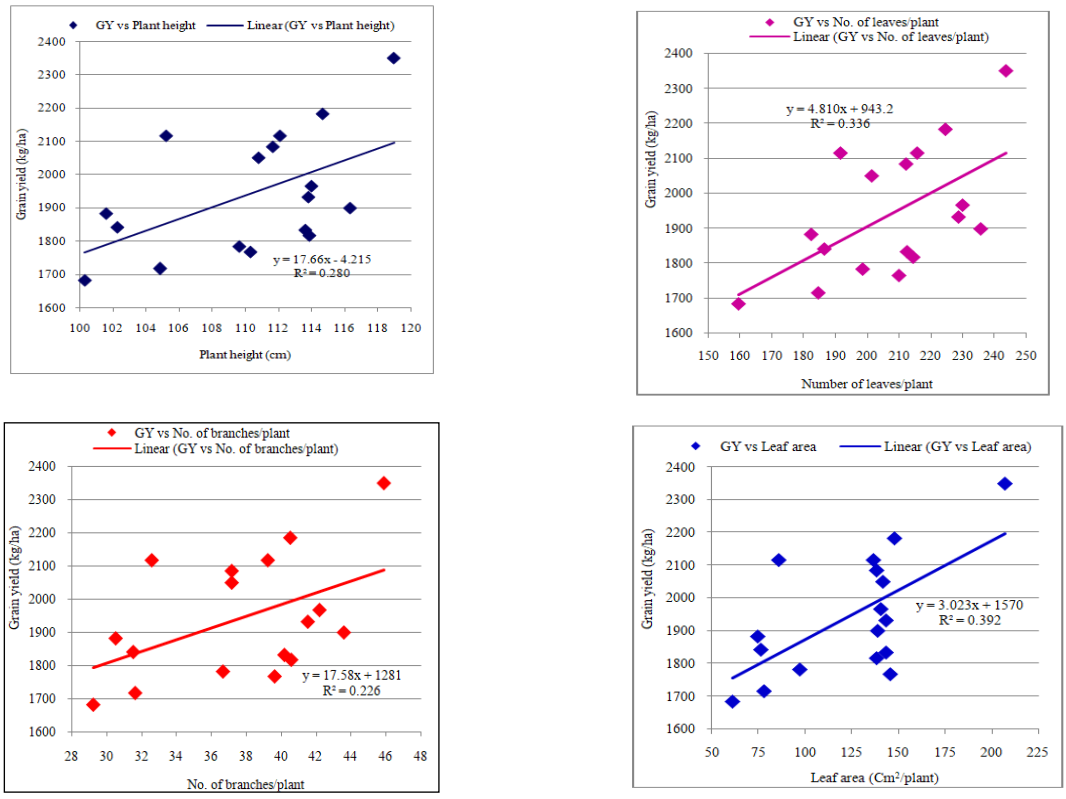

Fig. 2. Effect of plant height, number of leaves, number of branches and leaf area on quinoa yield.

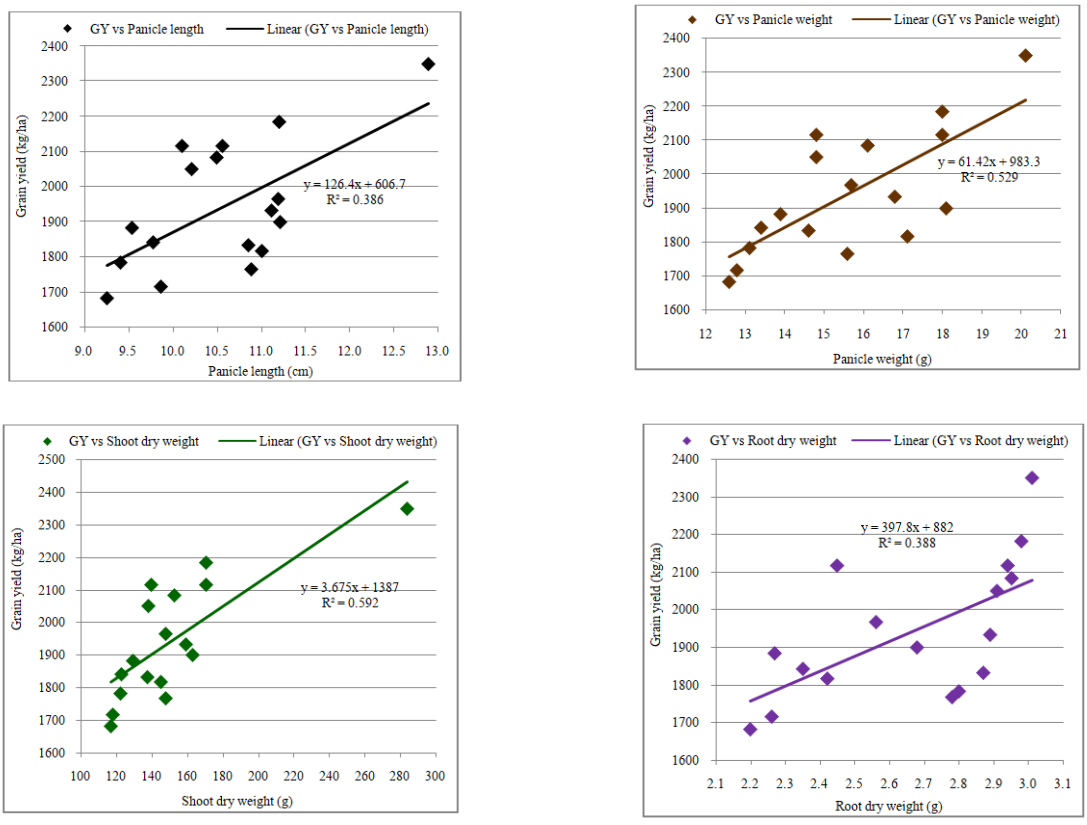

Fig. 3. Effect of panicle length, panicle weight, shoot dry weight and root dry weight on quinoa yield.

Table 1: Effect of microorganisms on plant height, number of leaves and branches in quinoa.

Treatments	Plant height (cm)	No. of leaves/plant	No. of branches/ plant	Increase (%) in plant height over control	Increase (%) in No. of leaves/ plant over control	Increase (%) in No. of branches/ plant over control
T1=Control (only RDF)	100.30^{k}	159.58^{l}	29.24^{l}			
T2=*Azotobacter chroococcum*	105.20^{ij}	191.50^{ij}	32.56^{ij}	4.7	16.7	10.2
T3=*Bacillus megaterium*	102.30^{jk}	186.58^{jk}	31.52^{jk}	2.0	14.5	7.2
T4=*Glomus fasciculatum*	104.87^{ij}	184.65^{jk}	31.63^{jk}	4.4	13.6	7.6
T5=*Frateuria aurantia*	101.62^{jk}	182.35^{k}	30.54^{k}	1.3	12.5	4.3
T6=*Pseudomonas fluorescens*	109.64^{hi}	198.56^{hi}	36.65^{hi}	8.5	19.6	20.2
T7=*Azotobacter chroococcum*+ *Bacillus megaterium*	110.80^{fgh}	201.36^{fgh}	37.15^{hi}	9.5	20.7	21.3
T8=*Azotobacter chroococcum* +*Glomus fasciculatum*	111.65^{efg}	212.30^{efg}	37.14^{hi}	10.2	24.8	21.3
T9=*Azotobacter chroococcum* +*Frateuria aurantia*	112.10^{def}	215.60^{e}	39.21^{g}	10.5	26.0	25.4
T10=*Azotobacter chroococcum* +*Pseudomonas fluorescens*	114.65^{bc}	224.50^{d}	40.54^{e}	12.5	28.9	27.9
T11=*Bacillus megaterium*+ *Glomus fasciculatum*	110.32^{gh}	209.80^{gh}	39.62^{fg}	9.1	23.9	26.2
T12=*Bacillus megaterium*+ *Frateuria aurantia*	113.60^{cd}	212.50^{efg}	40.21^{ef}	11.7	24.9	27.3
T13=*Bacillus megaterium*+ *Pseudomonas fluorescens*	113.80^{cd}	228.65^{c}	41.52^{d}	11.9	30.2	29.6
T14=*Glomus fasciculatum*+ *Pseudomonas fluorescens*	113.98^{c}	229.98^{c}	42.21^{c}	12.0	30.6	30.7
T15=*Glomus fasciculatum*+ *Frateuria aurantia*	113.89^{cde}	214.50^{ef}	40.56^{e}	11.9	25.6	27.9
T16=*Frateuria aurantia*+ *Pseudomonas fluorescens*	116.30^{b}	235.65^{b}	43.61^{b}	13.8	32.3	33.0
T17=*Azotobacter chroococcum* +*Bacillus megaterium*+ *Pseudomonas fluorescens*	118.97^{a}	243.51^{a}	45.89^{a}	15.7	34.5	36.3
Mean	110.23	207.74	37.64	9.3	23.7	22.3
SD	5.48	22.02	4.95	4.2	6.9	9.9
CV (%)	5.0	10.6	13.1	44.9	28.9	44.4

Treatment values with same alphabet are at par at p≤0.05

Effect of microbial inoculants on leaf area, panicle length, panicle weight and yield. Based on ANOVA, treatments were significantly different in influencing the panicle length and panicle weight at p<0.05 level of significance. Panicle length ranged from 9.25-12.89 cm with mean of 10.57 cm (CV of 8.5%). Panicle weight ranged from 12.6-20.1 g with mean of 15.6 g (CV of 13.9%). The treatment T17 involving *Azotobacter chroococcum+Bacillus megaterium+Pseudomonas fluorescens* provided significantly higher panicle length of 12.89 cm and panicle weight of 20.10 g, followed by T16 receiving *Frateuria aurantia+Pseudomonas fluorescens* with panicle length of 11.22 cm and panicle weight of 18.10 g. Minimum panicle length and panicle weight were attained by T1. Based on DMRT, T17 was superior compared to other treatments for attaining significantly higher panicle length and panicle weight at harvest of the crop (Table 2).

Based on ANOVA, treatments were significantly different in influencing quinoa grain yield at p<0.05 level of significance. Grain yield ranged from 1683-2350 kg/ha with mean of 1943 kg/ha (CV of 9.4%). Significantly higher yield of 2350 kg/ha was attained by T17 involving *Azotobacter chroococcum+Bacillus megaterium+Pseudomonas fluorescens*, while lowest yield of 1683 kg/ha was attained by T1 (Table 2). Based on DMRT, T17 was superior compared to other treatments for attaining significantly higher yield. Our results are in agreement with the results reported by Shehata *et al*. (2010) on celeriac plant and Erdal Elkoca *et al.* (2008) in chickpea.

Relationship between plant traits and yield parameters. Estimates of correlation between plant traits and grain yield of quinoa are given in Table 3. The plant height had a significant positive correlation with number of leaves/plant (0.957**) and number of branches/plant (0.980**); while number of leaves/plant had a significant positive correlation with number of branches/plant (0.968**). The panicle length and panicle weight had positive and significant correlation with plant height (0.873** and 0.838**), number of leaves/plant (0.901** and 0.871**) and number of branches/plant (0.897** and 0.840**) respectively. The panicle length had significant positive correlation with panicle weight (0.887**), stem dry weight (0.869**), root dry weight (0.595*), leaf area (0.922**); while panicle weight had

significant positive correlation with stem dry weight (0.844**), root dry weight (0.642**), leaf area (0.854**). The grain yield had significant positive correlation with plant height (0.529*) and number of leaves/plant (0.580*), panicle length (0.622**) and panicle weight (0.728**).

Table 2: Effect of microorganisms on panicle length, panicle weight and quinoa yield.

Treatments	Panicle length (cm)	Panicle weight(g)	Grain yield (kg/ha)
T1=Control (only RDF)	9.25^{k}	12.60^{op}	1683^{q}
T2=*Azotobacter chroococcum*	10.10^{g}	14.80^{i}	2117^{c}
T3=*Bacillus megaterium*	9.78^{h}	13.40^{l}	1842^{j}
T4=*Glomus fasciculatum*	9.86^{h}	12.80^{n}	1717^{op}
T5=*Frateuria aurantia*	9.54^{i}	13.90^{k}	1883^{i}
T6=*Pseudomonas fluorescens*	9.41^{j}	13.10^{m}	1783^{m}
T7=*Azotobacter chroococcum+Bacillus megaterium*	10.21^{g}	14.80^{i}	2050^{e}
T8=*Azotobacter chroococcum+Glomus fasciculatum*	10.50^{f}	16.10^{f}	2083^{d}
T9=*Azotobacter chroococcum+Frateuria aurantia*	10.56^{f}	18.00^{c}	2117^{c}
T10=*Azotobacter chroococcum+Pseudomonas fluorescens*	11.21^{b}	18.00^{c}	2183^{b}
T11=*Bacillus megaterium+Glomus fasciculatum*	10.89^{de}	15.60^{h}	1767^{n}
T12=*Bacillus megaterium+Frateuria aurantia*	10.86^{e}	14.60^{j}	1833^{k}
T13=*Bacillus megaterium+Pseudomonas fluorescens*	11.12^{bc}	16.80^{e}	1933^{g}
T14=*Glomus fasciculatum+Pseudomonas fluorescens*	11.20^{b}	15.70^{g}	1967^{f}
T15=*Glomus fasciculatum+Frateuria aurantia*	11.01^{cd}	17.10^{d}	1817^{l}
T16=*Frateuria aurantia+Pseudomonas fluorescens*	11.22^{b}	18.10^{b}	1900^{h}
T17=*Azotobacter chroococcum+Bacillus megaterium+Pseudomonas fluorescens*	12.89^{a}	20.10^{a}	2350^{a}
Mean	10.57	15.6	1943
SD	0.90	2.2	183
CV (%)	8.5	13.9	9.4

Treatment values with same alphabet are at par at p≤0.05

Table 3: Correlation between plant traits and yield parameters.

Trait-1	Trait-2	Correlation	Trait-1	Trait-2	Correlation
PH	NOL	0.957**	GY	PH	0.529*
PH	NOB	0.980**	GY	NOL	0.580*
NOL	NOB	0.968**	GY	NOB	0.476
PH	PL	0.873**	GY	PL	0.622**
PH	PW	0.838**	GY	PW	0.728**
NOL	PL	0.901**			
NOL	PW	0.871**			
NOB	PL	0.897**			
NOB	PW	0.840**			

Critical correlation coefficient at p<0.05 level of significance with 15 degrees of freedom = 0.482
Critical correlation coefficient at p<0.01 level of significance with 15 degrees of freedom = 0.606
* and ** indicate significance at p<0.05 and p<0.01 level of significance respectively
PH: Plant height; NOL: Number of leaves; NOB: Number of branches ; GY: Grain yield
PL: Panicle length; PW: Panicle weight

SUMMARY

A study was conducted to assess the effect of microbial inoculants on growth and yield of quinoa under glass house conditions in Department of Agricultural Microbiology, UAS, Bangalore. Five microbial cultures viz., *Azotobacter chroococcum*, *Bacillus megaterium, Fraturia aurantia, Pseudomonas fluorescens* and *Glomus fasciculatum* were used. Pure cultures of *Azotobacter chroococcum*, *Bacillus megaterium, Fraturia aurantia, Pseudomonas fluorescens* isolates were sub-cultured on specific medium and maintained in slants. Microbial inoculants of *Azotobacter chroococcum*, *Bacillus megaterium, Fraturia aurantia, Pseudomonas fluorescens* were mixed with carrier (talc) and kept for a week for stabilization at room temperature. About 10g of carrier based inoculants was applied to each pot and mixed thoroughly in top soil just before sowing. Seventeen treatments were tested for identifying a superior treatment for attaining maximum plant growth and yield. Based on DMRT, T17: *Azotobacter chroococcum+Bacillus megaterium+Pseudomonas fluorescens* superior with noticeably increased plant height, leaves per plant, branches per plant, panicle length, panicle weight, and grain yield of quinoa. We found strong positive connections between plant height and the number of leaves and branches per plant as well as between the number of leaves per plant and the number of branches per plant. Plant height, the number of leaves, and the number of branches per plant were significantly positively correlated with panicle length and panicle weight. Significant positive association between panicle weight and panicle length was observed. Plant height, leaf count, panicle length, and panicle

weight all significantly positively correlated with quinoa yield.

Based on regression model, quinoa yield had R^2 of 0.280, 0.336 and 0.226 for predicting yield with rate of change of 17.66, 4.81and 17.58 kg/ha for unit change through plant height, number of leaves/plant, number of branches/plant respectively. Similarly, yield had R^2 of 0.386 and 0.529 for predicting yield with rate of change of 126.4 and 61.42 kg/ha for unit change through panicle length and panicle weight respectively. The correlation between plant traits and quinoa yield and rate of change of yield for unit change in parameters indicated that treatments have positively influenced the plant traits, which in turn positively influenced the yield. T17: *Azotobacter chroococcum* + *Bacillus megaterium* + *Pseudomonas fluorescens* was superior with lowest rank sum of 21, while T10: *Azotobacter chroococcum* + *Pseudomonas fluorescens* was the 2nd best with rank sum of 60. We recommend these two superior treatments for attaining maximum plant growth and yield of quinoa. There is a need for testing the beneficial microorganisms in field condition for greater efficacy before making large scale recommendation to farmers for adoption under semi-arid Alfisols.

Acknowledgement. I am thankful to the department of agricultural microbiology, GKVK for providing me all the facilities to carry out my research effectively.

Conflict of Interest. None.

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How to cite this article: Ameer Pasha B., Salmankhan R.M., Parameshnaik C. and L. Krishna Naik (2023). Assessment of Effect of Beneficial Microorganisms on Plant Growth and Yield of Quinoa (*Chenopodium quinoa* Wild) under Semi-arid Alfisols. *Biological Forum – An International Journal, 15*(2): 1251-1258.