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Effect of NPK levels with and without biofertilizers on nutrient content and its uptake by quinoa and soil properties

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Abstract
A field experiment was conducted during *rabi* 2020-21 to study the effect of NPK and biofertilizer levels on N, P, K, S content and its uptake in Jawahar selection-1 cultivar of Quinoa. Ten Treatments *viz.*, T_1 (Control), T_2 (NPK @ 60:30:20 kg ha^{-1}), T_3 (NPK @ 90:45:30 kg ha^{-1}), T_4 (NPK @ 120:60:40 kg ha^{-1}), T_5 (T_2+*Azotobacter* and PSB @ 5 kg ha^{-1}), T_6 (T_3+*Azotobacter* and PSB @ 5 kg ha^{-1}), T_7 (T_4+*Azotobacter* and PSB @ 5 kg ha^{-1}), T_8 (T_5+VAM @ 6.25 kg ha^{-1}), T_9 (T_6+VAM @ 6.25 kg ha^{-1}) and T_{10} (T_7+VAM @ 6.25 kg ha^{-1}) were evaluated under randomized block design replicated thrice. The results of the experiment suggested that contents of N, P, K & S in grain and straw were significantly affected by the addition of nutrients through various NPK levels and reflected increasing trend from T_2 over control. Higher NPK levels improved the content of nutrients in grain over the preceding NPK levels. The combined use of NPK nutrients with different levels in combination with biofertilizers under T_4 to T_{10} treatments significantly affected the NPK content of grain and stover. Nutrient uptake was comparatively higher in quinoa seeds except K which was highest in stover. Significant variation in soil available N, P, and K was observed due to the effect of treatments; however the physico-chemical properties remained similar with non-significant variation after crop harvest.

Keywords: Quinoa, NPK, biofertilizer, *Azotobacter*, PSB, VAM, nutrient content, uptake

Introduction
Quinoa (*Chenopodium quinoa*) an annual herbaceous plant belongs to the Amaranthaceae family, discovered as a health food by North Americans and Europeans in the 1970's and its popularity has increased dramatically in recent years because it is gluten-free (useful for diabetic patients) and is high in protein. It is cultivated in the world with an area of 126 thousand hectares with a production of 103 thousand tones. Bolivia in South America is the largest producer of quinoa with 46 percent of world production followed by Peru with 42 percent and United States of America with 6.3 percent (FAOSTAT, 2013) [6]. In India, quinoa was cultivated in an area of 440 hectares with an average yield of 1053 tones (Srinivasa Rao, 2015) [11].

Quinoa has a taproot system and penetrates to a depth of 1.5 m below the surface, protecting it from drought conditions with broad leaves. The inflorescence is 15–70 cm tall in a panicle and rises from the top of the plant and the axils of the lower leaves, usually about 1–2 m erect. According to Shams and Bhargava *et al.* (2006) [3] quinoa seeds are small with a diameter of about 1–2.5 mm and the weight of 1,000 seeds was 1.4–4.3 g. The growth period of quinoa is between 70 and 200 days and some entries do not mature in some places. Quinoa is a fast-growing plant with alternate, coarse-toothed, triangular to oval leaves and is similar to the common North American weed (*Chenopodium album* called lamb's quarter or goosefoot). Each inflorescence produces hundreds of small achenes about 2 mm in diameter. Quinoa is an achene (a seed-like fruit with a hard coat) with a variety of colors from white or pale yellow to orange, red, brown and black. It has greater plasticity to adapt to photoperiod, altitude, soil pH etc. It can be grown in temperatures up to 3,900 m above mean sea level and a pH range of 6 to 8.5 and in subtropical to tropical and humid regions. The base temperature of quinoa is 30 °C with an optimum temperature of 15-30 °C and can tolerate maximum temperature of 50 °C. The quinoa crop is usually grown on less fertile soils or marginal lands under moisture stressed conditions which is the limiting factor for growth and development. Under these conditions, optimal nutrient supplementation is obligatory to reduce the effects of soil nutrient status and promote good plant growth. However, quinoa is highly sensitive to soil nitrogen (Early *et al.* 2005) [4]. Therefore, it becomes more important to establish the density of different plants with respect to its growth and productivity and the differences innutrient management. Keeping in view the above facts, a study was undertaken to assess the effect of NPK levels with and without biofertilizers on nutrient content and its uptake by quinoa and soil properties.

Materials and Methods

An investigation was undertaken during *rabi* 2020-21 at the research farm of College of Agriculture, Jawaharlal Nehru Krishi Vishwavidyalaya Jabalpur. Experiment was conducted on Jawahar Selection 1 cultivar of quinoa in randomized block design with three replications using 10 treatments *viz.* T_1 (Control), T_2 (NPK @ 60:30:20kg ha^{-1}), T_3 (NPK @ 90:45:30 kg ha^{-1}), T_4 (NPK @ 120:60:40 kg ha^{-1}), T_5 (T_2+*Azatobacter* and PSB @ 5 kg ha^{-1}), T_6 (T_3+*Azatobacter* and PSB @ 5 kg ha^{-1}), T_7 (T_4+*Azatobacter* and PSB @ 5 kg ha^{-1}), T_8 (T_5+VAM @ 6.25 kg ha^{-1}), T_9 (T_6+VAM @ 6.25 kg ha^{-1}) and T_{10} (T_7+VAM @ 6.25 kg ha^{-1}). Plot size was kept 5.25 m × 2 m, spacing was maintained 35 cm between rows and 10 cm between plants. A plant sample from each plot was collected randomly at harvest stage. Seeds were separated and the remaining portion was used for further analysis. Plant samples were dried and straw samples were digested and analyzed for N, P, K and S using standard methods. The data analyzed by the method of analysis of variance. The 'F' test was used for judging the significance at 5% of the treatment mean and the difference between two treatments mean was judged by using critical difference Steel *et al.* (1997) [13]. Treatment wise soil samples were analyzed for pH, EC, organic carbon, Available N, P, K and micronutrients.

Results and Discussion

Nutrient content and their uptake

It is evident from the data that the content of nutrients in grain and straw were significantly affected by the addition of nutrients through different NPK levels than the control. Optimum NPK levels increased the content of nutrients in grain over the lower NPK levels (Table 1). This might be due to enhanced availability of nutrients through higher levels of nutrients. The findings are in agreement with those of Gomaa (2013) [5]. The combined use of NPK nutrients with different levels in combination with biofertilizers significantly affected the NPK content of grain and stover. The uptake of N, P, K and S was the lowest in T_1 treatment. Cumulative uptake of NPKS increased with their application in the crop because of increased availability of these nutrients resulted in higher biomass yield.

The data given in Table 1 showed that maximum N content (2.19%) recorded with T_{10} (NPK 120:60:40 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}), which was at par with T_7, T_4 and T_9 treatments (2.11, 2.08 & 1.99%), while minimum content (1.47%) was noted in the control. The N content (%) in quinoa stover revealed that different doses of NPK with and without biofertilizers combination improved the N content in stover as compared to control. Nitrogen content in stover ranged from 1.06 to 2.08% across the treatments. Remarkably higher N uptake in seed and stover (35.74 & 41.33 kg ha^{-1}) was recorded under treatment T_{10}, while treatment T_7 remained statistically at par with T_{10} (Table 2). Significantly higher content of N in grain at optimum level of NPK might be due to the presence of nitrogen fixing microorganism which are capable of transforming unavailable atmospheric nitrogen into available form and application of biofertilizers must have increased N efficiency by increasing N content and its uptake in plants. These results are in confirmation with the findings of Stajkovic *et al.* (2011) [12].

Table 1 further suggested that, the highest phosphorus content in seed (0.73%) was recorded with T_{10} which was statistically at par with T_9, T_7 and T_4 treatments, likewise in stover it was recorded to be maximum in T_{10} (0.23%) followed by T_7 and T_4 treatments (0.23 and 0.22%). Similarly, significantly highest P uptake in seed and stover (7.72 & 4.58 kg ha^{-1}) was recorded under treatment T_{10} (Table 2) while treatment T_7 remained statistically at par with T_{10} (7.12 & 4.39 kg ha^{-1} in seed and stover). This might be due to the presence of PSB and VAM, that solubilized insoluble phosphorous and helped in phosphorus absorption and also produced phytohormones such as auxins, cytokinins, gibberellins and abscisic acids which promoted the plant growth and possibly increased the biomass and P uptake. These results are in accordance with the finding obtained by Suresh *et al.* (2010) [14].

Data regarding the effect of various treatments on K content in seed and stover is given in Table 1 showed that treatments exhibited their significant effect on K content in seed and stover. Significantly higher K content in seed and stover (1.76 and 2.21%) was recorded under treatment T_{10} while treatments T_7 and T_4 were remained statistically at par with T_{10}. Lowest K content in seed and stover (1.16 and 1.62%) was recorded under treatment T_1 (control). These finding are in conformity with those of Fawy, H.A. *et al.* (2015) [7] who stated that the average values of N, P, and K contents of quinoa straw and seeds during the two studied seasons increased with increasing N and organic amendments rates. K uptake in seed and stover presented in Table 2 revealed that all treatments reflected their significant effect on K uptake in seed and stover. Significantly highest K uptake in seed and stover (28.67 and 44.05 kg ha^{-1}) was recorded under treatment T_{10} while treatment T_7 remained statistically at par with T_{10}. The lowest K uptake in seed and stover (11.32 and 20.49 kg ha-1) was recorded under T_1. Similar results were reported by Satyajeet *et al.* (2007) [8].

Among various treatments, the highest sulphur content in seed and stover (0.47 and 0.16%) was recorded with T_{10}. S content in seed was statistically at par with T_{10} under T_7, T_9 and T_4 treatments; however, in stover it was at par with T_9, T_7, T_6 and T_4 treatments (Table 1). The data related to the S uptake by seed and stover are presented in Table 2 reflected that the highest sulphur uptake in seed and stover (7.67 and 3.05 kg ha^{-1}) was recorded with T_{10} which was statistically at par with treatment T_7 in seed and; T_7, T_9 and T_4 treatments in stover. The lowest sulphur uptake in seed and stover (2.50 and 1.01 kg ha^{-1}) was recorded under control plot.

Physico-chemical properties of soil

The result of investigation given in Table 3 revealed that the soil pH, EC and OC were remain unchanged under different NPK levels with and without biofertilizers. This could probably be due to high buffering capacity of the soils under study. Similar results were reported by Aphale *et al.* (2005) [1].

The highest available N status (182 kg ha^{-1}) was registered under T_{10} while treatments T_7 and T_4 were remained statistically at par with T_{10} (Table 3), which may be due to the added N through inorganic N fertilizer with and without biofertilizers. This perhaps due to integration of *Azotobacter* with NPK resulted in positive buildup of available N over the respective initial status. The results also confirm the findings of Singh *et al.* (2001) [10].

Available P status in post-harvest soil significantly increased with PSB and VAM application. Application of NPK with PSB and VAM recorded significantly higher available P in T_{10} and T_7 (12.52 and 12.07 kg ha^{-1}) than the other treatments (Table 3). The increase in available P with PSB and VAM addition might be due to release of more P from organic compounds, as well as from fixed form of P, increase in microbial population as well as decomposition product of humic substances (Shinde and Solanki 1991) [9].

The highest available P status (240 kg ha^{-1}) was reported under T_{10} while treatments T_3, T_4, T_6, T_7 and T_9 treatments were remained statistically at par with T_{10} (Table 3). The available K status in post-harvest soil increased at higher level over their respective initial status, which may be due to the added K through inorganic K fertilizer with and without biofertilizer at higher levels. However, increase in available K status might be due to mobilization of K from reserve pool. Bansal and Jain (1988) [2] also reported that under balanced fertilization condition and in continuous cropping, most of K is derived from non exchangeable pool.

Under the micronutrients, Fe, Zn, Mn, and Cu were estimated and the treatment-wise data is shown in Table 4, indicated that no significant effect of various NPK treatments with and without biofertilizers was observed on these micronutrients in the experimental soil after crop harvest.

Table 1: Effect of NPK levels with and without biofertilizer on N, P, K and S content in quinoa grain and stover in various treatments

	Treatments	Nutrient concentration in grain (%)				Nutrient concentration in Stover (%)			
		N	P	K	S	N	P	K	S
T_1	Control	1.42	0.21	1.16	0.26	1.06	0.15	1.62	0.08
T_2	NPK 60:30:20 kg ha^{-1}	1.60	0.26	1.24	0.33	1.19	0.17	1.74	0.11
T_3	NPK 90:45:30 kg ha^{-1}	1.90	0.32	1.35	0.38	1.64	0.21	1.80	0.11
T_4	NPK 120:60:40 kg ha^{-1}	2.08	0.43	1.56	0.42	1.97	0.22	1.97	0.13
T_5	NPK 60:30:20 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each	1.68	0.28	1.28	0.34	1.30	0.18	1.73	0.11
T_6	NPK 90:45:30 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each	1.93	0.36	1.34	0.41	1.65	0.20	1.83	0.13
T_7	NPK 120:60:40 kg ha-1 + *Azotobacter* & PSB 5 kg ha^{-1} each	2.11	0.45	1.63	0.46	1.98	0.23	2.12	0.13
T_8	NPK 60:30:20 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}	1.75	0.28	1.33	0.36	1.56	0.19	1.77	0.12
T_9	NPK 90:45:30 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}	1.99	0.39	1.48	0.42	1.81	0.21	1.91	0.15
T_{10}	NPK120:60:40 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}	2.19	0.47	1.76	0.47	2.08	0.23	2.21	0.15
	S.Em±	0.09	0.02	0.11	0.01	0.091	0.012	0.084	0.013
	CD at 5%	0.29	0.07	0.35	0.05	0.270	0.036	0.248	0.038

Table 2: Effect of NPK levels with and without biofertilizer on N, P, K and S uptake by quinoa grain and stover in various treatments

	Treatments	Nutrient uptake by grain (Kg ha^{-1})				Nutrient uptake by stover (Kg ha^{-1})			
		N	P	K	S	N	P	K	S
T_1	Control	13.82	2.01	11.32	2.50	13.38	1.85	20.49	1.01
T_2	NPK 60:30:20 kg ha^{-1}	18.24	3.00	14.17	3.80	17.67	2.52	25.79	1.58
T_3	NPK 90:45:30 kg ha^{-1}	24.64	4.11	17.51	4.93	27.30	3.50	29.97	1.83
T_4	NPK 120:60:40 kg ha^{-1}	31.66	6.60	23.74	6.39	36.43	4.06	36.30	2.46
T_5	NPK 60:30:20 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each	20.33	3.35	15.45	4.15	20.28	2.86	27.04	1.77
T_6	NPK 90:45:30 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each	26.56	4.91	18.44	5.60	29.38	3.57	32.71	2.26
T_7	NPK 120:60:40 kg ha-1 + *Azotobacter* & PSB 5 kg ha^{-1} each	33.40	7.12	25.75	7.23	37.78	4.39	40.45	2.54
T_8	NPK 60:30:20 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}	22.24	3.60	16.86	4.53	25.29	3.07	28.64	1.89
T_9	NPK 90:45:30 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}	30.01	5.83	22.27	6.38	32.77	3.79	34.51	2.65
T_{10}	NPK120:60:40 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}	35.74	7.72	28.67	7.67	41.33	4.58	44.05	3.05
	S.Em±	1.22	0.31	1.28	0.25	1.53	0.19	1.60	0.23
	CD at 5%	3.64	0.93	3.81	0.76	4.56	0.59	4.75	0.68

Table 3: Physico-chemical properties of soil and available major nutrients after crop harvest under different NPK levels with and without biofertilizer in various treatments

	Treatments	pH	EC (dSm^{-1})	OC (g kg^{-1})	Available nutrients (kg ha^{-1})		
					N	P	K
	Initial soil test value	7.60	0.18	3.84	168	11.46	232
T_1	Control	7.39	0.16	3.62	154	9.07	217
T_2	NPK 60:30:20 kg ha^{-1}	7.55	0.16	3.32	160	9.23	221
T_3	NPK 90:45:30 kg ha^{-1}	7.53	0.17	3.58	169	11.50	230
T_4	NPK 120:60:40 kg ha^{-1}	7.59	0.18	3.86	179	11.94	238
T_5	NPK 60:30:20 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each	7.52	0.17	4.02	162	10.58	221
T_6	NPK 90:45:30 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each	7.59	0.15	3.74	171	11.64	230

T_7	NPK 120:60:40 kg ha-1 + *Azotobacter* & PSB 5 kg ha^{-1} each	7.60	0.14	3.53	182	12.07	239
T_8	NPK 60:30:20 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}	7.40	0.17	3.70	162	10.90	222
T_9	NPK 90:45:30 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}	7.56	0.16	3.52	173	11.80	231
T_{10}	NPK120:60:40 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}	7.56	0.17	4.06	182	12.52	240
S.Em±		0.14	0.03	0.011	4.64	0.22	5.89
CD at 5%		NS	NS	NS	13.80	0.62	17.52

Table 4: Micronutrients status in soil after harvest of quinoa under different NPK levels with and without biofertilizer in various treatments

Treatments		Available micronutrients (mg kg^{-1})			
		Fe	**Zn**	**Mn**	**Cu**
Initial soil test value		**12.04**	**0.85**	**2.17**	**1.32**
T_1	Control	11.95	0.82	1.15	1.28
T_2	NPK 60:30:20 kg ha^{-1}	11.92	0.82	1.13	1.28
T_3	NPK 90:45:30 kg ha^{-1}	11.83	0.81	1.11	1.28
T_4	NPK 120:60:40 kg ha^{-1}	11.98	0.83	1.14	1.27
T_5	NPK 60:30:20 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each	12.11	0.84	1.13	1.28
T_6	NPK 90:45:30 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each	11.93	0.81	1.11	1.28
T_7	NPK 120:60:40 kg ha-1 + *Azotobacter* & PSB 5 kg ha^{-1} each	11.92	0.81	1.15	1.31
T_8	NPK 60:30:20 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}	12.04	0.79	1.19	1.27
T_9	NPK 90:45:30 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}	11.94	0.84	1.15	1.27
T_{10}	NPK120:60:40 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}	12.04	0.81	1.15	1.30
SEm±		0.06	0.02	0.03	0.02
CD at 5%		NS	NS	NS	NS

Conclusions

On the basis of the above findings it may be determined that nutrient composition in the plant increased proportionately with successive addition of NPK with biofertilizers. However, the lowest content was noted in control while, an increasing trend was observed with higher NPK levels from T_2. Similar trend was also observed for the N, P, K, and S uptake pattern in quinoa crop. In general, higher nutrient content and uptake was recorded in seed compared to that of stover, except K which was maximum in stover with respect to content and uptake both. Physico-chemical properties of the soil remained alike with non-significant variation after crop harvest, however significant variation in available N, P, and K was observed due to the effect of treatments.

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