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Mohan Paradkar
Department of Soil Science, College of Agriculture, Jabalpur, Madhya Pradesh, India

AK Singh
Krishi Vigyan Kendra, JNKVV, Jabalpur, Madhya Pradesh, India

BS Dwivedi
Krishi Vigyan Kendra, JNKVV, Jabalpur, Madhya Pradesh, India

Nitin Singhai
Krishi Vigyan Kendra, JNKVV, Jabalpur, Madhya Pradesh, India

Yati Raj Khare
Krishi Vigyan Kendra, JNKVV, Jabalpur, Madhya Pradesh, India

Corresponding Author:
Mohan Paradkar
Department of Soil Science, College of Agriculture, Jabalpur, Madhya Pradesh, India

Response of NPK levels and biofertilizers on growth, yield and quality of quinoa (*Chenopodium quinoa*)

Mohan Paradkar, AK Singh, BS Dwivedi, Nitin Singhai and Yati Raj Khare

Abstract
An investigation was undertaken to study the effect of NPK and biofertilizer levels on growth, yield and quality parameters in Jawahar Selection 1 cultivar of Quinoa. Ten treatments *viz.*, T_1 (Control), T_2 (NPK @ 60:30:20), T_3 (NPK @ 90:45:20), T_4 (NPK @ 120:60:40), 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 using randomized block design replicated thrice. The findings of the experiment specified that the plant height, plant biomass, grain, stover yield, test weight and protein content in seed was significantly higher in T_{10} at harvest, followed by T_7 and T_4 as compared to remaining preceding treatments, however no significant difference in carbohydrate content was seen among the treatments although it was also highest in T_{10} followed by T_6 and T_9. Significant response of biofertilizers (*Azotobacter*, PSB & VAM) registered in respect of quality with regard to seed protein content, growth and yield attributes.

Keywords: NPK, biofertilizer, quinoa, *Azotobacter*, PSB, VAM, yield, protein

Introduction
Quinoa (*Chenopodium quinoa* willd.) is an annual herbaceous plant that belongs to the Amaranthaceae family, but previously belonged to the Chenopodiaceae family that originated on the Pacific slopes of the Andes in South America (FAOSTAT, 2013) [8]. In India, quinoa was cultivated in an area of 440 hectares with an average yield of 1053 tonnes (Srinivasarao, 2015) [19]. 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 of quinoa ranges from 7.47 to 22.08 per cent with higher concentrations of lysine, isoleucine, methionine, histidine, cystine and glycine. The total ash content is 3.4 per cent containing high amount of Ca, Fe, Zn, Cu and Mn. The oil content is 1.8 to 9.5 per cent and rich in essential fatty acids like linoleate and linolenate. This is very important for the nutritional value of pseudo cereals, as a high content of dietary fibres has a positive effect on reducing the risk of cancer. In general, quinoa has a higher total mineral content than other grains such as rye and wheat.

Nowadays, it has become necessary to search for untraditional fertilizers as substitutes for chemical nitrogen, phosphorus and potassium ones. Phosphorus nutrition is doubly critical because the total supply of phosphorus in most soils is low and is not readily available for the plant use. Remarkable effects of untraditional fertilizers, especially the biofertilizers have been reported on growth and yield of plants. Mohamed and Medani (2005) [11] found that *Azotobacter* play a key role in nitrogen nutrition of cereals and produce plant growth hormones IAA, GA and Cytokinin which enhance germination efficiency and stimulate rooting. The quinoa crop is usually grown on soils with poor fertility and moisture is the limiting factor for growth and development. Under these conditions, optimal nutrient supplementation is necessary 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) [5]. Therefore, it becomes more important to ascertain the density of different plants with respect to its growth and productivity and the differences in nutrient management. Keeping in view the above, the present investigation was under taken to study the effect of different NPK levels on growth yield and quality of quinoa.

Materials and Methods

Present investigation was under taken during *rabi* 2020-21 at the research farm of College of Agriculture, Jawaharlal Nehru Krishi Vishwavidyalaya Jabalpur. Experiment was conducted on Jawahar Selection 1 variety of quinoa in randomized block design with three replications using 10 treatments *viz.*,T_1 (Control), T_2 (NPK @ 60:30:20), T_3 (NPK @ 90:45:20), T_4 (NPK @ 120:60:40), 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 5.25 m × 2.00 m with spacing of 35cm × 10cm. Observations on plant height and dry matter production was recorded at 30, 50, 70, 90 DAS and at harvest. Grain yield, stover yield and test weight was calculated after harvesting. Protein content of quinoa grain was estimated as per the procedure suggested by Piper, 1950 and total carbohydrate was estimated by hydrolysis method as described in AOAC (1995) [1].

Results and Discussion

Plant height

It is evident from Table 1 that among the NPK levels, T_{10} (NPK 120:60:40 kg ha^{-1} + *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}) recorded significantly the tallest plant (26.7, 59.1, 90.2, 121.9 and 123.0 cm) while, the shortest plant (19.5, 48.3, 79.0, 106.7 and 107.7 cm) was noted with T_1 (control) at 30, 50, 70, 90 DAS and at harvest, respectively. Higher NPK levels resulted in higher plant height. It might be due to the role of nitrogen in the synthesis of growth promoting hormones like auxin and cytokinin which have their specific role in increasing the plants height which may also be affected by biofertilizers. Similar observations have been also reported by Barsa *et al.* (2014) [3], Geren (2015) [6], Shoman (2018) [18], and Naik *et al.* (2020) [12].

Plant biomass

Among the treatments, T_{10} (NPK 120:60:40 kg ha^{-1} + *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}) recorded significantly the highest dry matter accumulation plant m^{-2} (186, 273, 402, 591 and 725 g) followed by T_7 (NPK 120:60:40 kg ha^{-1} + *Azotobacter* & PSB 5 kg ha^{-1} each) with non-significant difference whereas, the lowest biomass production (165, 243, 357, 480 and 582 g) was observed in T_1 (control plot) at 30, 50, 70, 90 DAS and at harvest, respectively (Table 1). It might be due to the higher availability of plant nutrients especially NPK which have role in the dry matter production by converting source to sink in the plant. Similar findings have been reported by Neelam *et al.* (2009) [13], Ioanna *et al.* (2013) [10] Barsa *et al.* (2014) [3], and Shah *et al.* (2020) [16].

Grain yield

It is evident from the data given in Table 2 that the highest grain yield of quinoa was recorded under treatment T_{10} (NPK 120:60:40 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}) followed by T_7 (NPK 120:60:40 kg ha^{-1} + *Azotobacter* & PSB 5 kg ha^{-1} each) i.e., 1632 and 1522 kg $ha^{-1}$with non-significant difference when compared to the lowest yield (973 kg ha^{-1}) recorded in treatment T_1 (Control). Combined application of biofertilizers in other NPK levels increased the grain yield significantly over deprived of biofertilizers applied treatments. This might be due to the increasing NPK levels resulted in greater accumulation of carbohydrates, protein and their translocation to the productive organs, which in turn, improved all growth and yield attributing characters resulting more grain yield. Besides this the addition of NPK provided adequate and balanced quantity of plant nutrients. The result was supported by the findings of Geren (2015) [6], Varalakshmi *et al.* (2016) [20], Awadalla and Morsy (2017) [2] and Naik *et al.* (2018) [12] in quinoa.

Stover yield

The highest stover yield of quinoa was recorded under treatment T_{10} (NPK 120:60:40 kg ha^{-1}+ *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}) followed by T_7 (NPK 120:60:40 kg ha^{-1} + *Azotobacter* & PSB 5 kg ha^{-1} each) *i.e.*, 1990 and 1908 kg ha^{-1} with non-significant difference as compared to the lowest yield (1262 kg ha^{-1}) recorded in treatment T_1-control (Table 2). The dose of NPK alone in T_4 (NPK 120:60:40 $kgha^{-1}$) was found to be significantly better than the T_2 (NPK 60:30:20 $kgha^{-1}$) and T_3 (NPK 90:45:30 kg ha^{-1}) registering an additional grain yield of 33.5 and 17.34% respectively. Combined application of biofertilizers in other NPK levels increased the grain as well as straw yield significantly over deprived of biofertilizers applied treatments. These findings have been supported by Shams (2012) [17], Bilalis *et al.* (2014) [4] and Shoman (2018) [18].

Test Weight

The data given in Table 2 indicated that the highest test weight (3.23 g) was recorded with treatment T_{10} (NPK 120:60:40 kg ha^{-1} + *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}) followed by 3.21g inT_7 (NPK 120:60:40 kg ha^{-1} + *Azotobacter* & PSB 5 kg ha^{-1} each), while, lowest test weight (2.84 g) was observed in T_1 (control). This might be due to higher dry matter accumulation in the T_{10} treatment. The result was supported by Weisany *et al.* (2013) [22] and Gomaa (2013) [7] who stated that nitrogen fertilizers application in quinoa with nitrobin increased the average thousand grain weight from 0 (3.3 g) to 119 (4.9 g) kg N ha^{-1}.

Protein Content

A perusal of the data given in Table 2 designated that among various NPK levels, the highest protein content (13.67%) was recorded with T_{10} (NPK 120:60:40 kg ha^{-1} + *Azotobacter* & PSB 5 kg ha^{-1} each + VAM @ 6.25 kg ha^{-1}) followed by 13.19 and 13% in T_7 & T_4 (NPK 120:60:40 kg ha^{-1} + *Azotobacter* & PSB 5 kg ha^{-1} each with VAM @ 6.25 kg ha^{-1} and without VAM respectively). The lowest protein content (9.23%) was recorded in T_1 (control). This is due to the fact that nitrogen is the most important element in protein synthesis as N is the base of nucleic acid and protein building. Hence an increase in optimum conditions with the increased availability of nitrogen through synthesized chemical and biofertilizers application increased the protein content in grain. The result was supported by Geren (2015) [6], Awadalla and Morsy (2017) [2], Shoman (2018) [18], and Wang *et al.* (2020) [21].

Carbohydrate content

The use of NPK fertilizers in combination with biofertilizers established the fact that the plant absorbs nutrients proportionally as the soil accessible pool is concentrated with progressively increasing fertilizers doses. The carbohydrate content of quinoa grain ranged from 64.22 to 66.21 percent under various treatments (Table 2). There was no significant difference in carbohydrate content of quinoa grain the various treatments evaluated. Similar findings were given by Repo-Carrasco *et al.* (2003) [15].

Table 1: Response of NPK and biofertilizer levels on plant height and dry matter production of Quinoa

Treatments		Plantheight (cm)					Plant biomass (g m^{-2})				
		30 DAS	50 DAS	70 DAS	90 DAS	At harvest	30 DAS	50 DAS	70 DAS	90 DAS	At harvest
T1	Control	19.1	48.0	79.0	106.7	107.7	165	243	357	480	582
T2	NPK-60:30:20 kgha-1	21.3	53.2	84.2	114.2	115.4	171	252	371	492	606
T3	NPK-90:45:30 kg ha-1	22.2	54.2	85.2	115.3	116.6	178	260	382	512	641
T4	NPK-120:60:40 kg ha-1	23.3	55.3	86.3	116.4	117.8	182	266	397	576	709
T5	NPK-60:30:20 kg ha-1+ *Azotobacter* & PSB 5 kg ha-1each	21.6	53.6	84.6	114.6	116.1	174	254	373	498	619
T6	NPK-90:45:30 kg ha-1+ *Azotobacter* & PSB 5 kg ha-1each	22.5	54.5	85.5	115.6	117.2	181	263	386	516	652
T7	NPK-120:60:40kgha-1+ *Azotobacter* & PSB 5 kg ha-1 each	25.5	57.6	88.6	118.6	120.3	185	272	401	584	719
T8	NPK- 60:30:20 kg ha-1 + *Azotobacter* & PSB 5 kg ha-1 each + VAM @ 6.25 kg ha^{-1}	22.2	54.3	85.3	115.3	117.2	177	257	375	506	625
T9	NPK-90:45:30 kg ha-1 + *Azotobacter* & PSB 5 kg ha-1 each + VAM @ 6.25 kg ha^{-1}	24.5	56.2	87.2	117.2	119.1	182	265	388	527	658
T10	NPK-120:60:40 kg ha-1 + *Azotobacter* & PSB 5 kg ha-1 each + VAM @ 6.25 kg ha^{-1}	26.7	59.1	90.2	121.9	123.0	186	273	402	591	725
S.Em±		0.42	0.54	0.85	1.12	1.17	0.42	1.25	2.62	4.06	9.04
CD at 5% level		1.27	1.61	2.53	3.34	3.48	1.27	3.73	7.78	12.07	26.88

Table 2: Response of NPK and biofertilizer levels on yield, test weight, protein and carbohydrate content of Quinoa

Treatments		Yield (kg ha-1)		Test weight (g)	Protein content (%) in seed	Carbohydrate content (%) in seed
		Grain yield	Stover yield			
T1	Control	973	1262	2.84	9.23	64.41
T2	NPK-60:30:20 kg ha-1	1140	1485	3.08	9.98	64.79
T3	NPK-90:45:30 kg ha-1	1297	1668	3.11	11.87	65.47
T4	NPK-120:60:40 kg ha-1	1522	1846	3.15	13.00	65.57
T5	NPK-60:30:20 kg ha-1 + *Azotobacter* & PSB 5 kg ha-1 each	1210	1560	3.10	10.40	64.22
T6	NPK-90:45:30 kg ha-1 + *Azotobacter* & PSB 5 kg ha-1each	1376	1784	3.14	12.04	66.01
T7	NPK-120:60:40 kg ha-1 + *Azotobacter* & PSB 5 kg ha-1 each	1583	1908	3.21	13.19	65.40
T8	NPK- 60:30:20 kg ha-1 + *Azotobacter* & PSB 5 kg ha-1 each + VAM @ 6.25 kg ha^{-1}	1271	1618	3.14	10.92	64.69
T9	NPK-90:45:30 kg ha-1 + *Azotobacter* & PSB 5 kg ha-1 each + VAM @ 6.25 kg ha^{-1}	1508	1807	3.16	12.42	65.89
T10	NPK-120:60:40 kg ha-1 + *Azotobacter* & PSB 5 kg ha-1 each + VAM @ 6.25 kg ha^{-1}	1632	1990	3.23	13.67	66.21
S.Em±		46.13	87.29	0.01	0.61	0.45
CD at 5% level		137.07	259.37	0.03	1.82	NS

Conclusions

Application of NPK @ 120:60:40 kgha^{-1} with *Azotobacter* and PSB @ 5 kg ha^{-1} each showed significant improvement in growth and yield attributes of quinoa. However, these parameters were non-significantly higher under same NPK level and biofertilizers (*Azotobacter* & PSB) with VAM @ 6.25 kg ha^{-1}. Application of biofertilizers (*Azotobacter* and PSB 5 kgha^{-1} each) showed significant response with respect to protein content in quinoa seed.

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