The Influence of Integrated Nutrient Management on majornutrient status and physico-chemical properties of soilin Quinoa (*Chenopodium quinoa* Willd.)

ABSTRACT

A field experiment was conducted during *rabi* 2022-23 to study the effect of Integrated Nutrient Managementon physical and chemical properties of soil such as soil bulk density, maximum water holding capacity, pH, electrical conductivity, organic carbon, available major nutrients were investigated in anexperiment comprising eleven treatments replicated thrice in randomized complete block design with quinoa. The results of the experiment suggested that soilphysico-chemical properties like maximum water holding capacity, organic carbon had significantly influenced with the application of 50% nitrogen dose (ND) + 50% N through FYM + seed treatment (Azotobacter + PSB). Soil major nutrients like nitrogen, phosphorus and potassium had a higher significant effect with the application of 50% nitrogen dose (ND)+ 50% N through vermicompost(VC) + seed treatment (Azotobacter + PSB) in comparison to application of 100% fertilizer dose. In the other hand, soil propertieslike bulk density, pH, electrical conductivitydid not have a significant influence with the practice of Integrated Nutrient Management in quinoa.

Key words: Integrated nutrient management, quinoa, soil physical and chemical properties.

1. Introduction

Quinoa(*Chenopodium quinoa* Willd.), a nutritious pseudo-cereal, is an annual herbaceous plant from the Amaranthaceae family, originating in South America and used by the Inca civilization since 5,000 B.C. It is gluten-free, suitable for diabetic patientsand high in protein. Discovered by North Americans and Europeans in the 1970s, quinoa has gained popularity due to its high protein content and amino acid content. It contains Ca, Fe, Zn, Cu, and Mn, and has an oil content of 1.8 to 9.5%. Quinoa is also high in linoleate and linolenate, two essential fatty acids. The FAO designated 2013 as the International Year of Quinoa (Bhargava *et al*., 2006), highlighting its nutritional value. Quinoa can tolerate various environmental conditions, including pH ranging from 6 to 8.5, temperature ranging from subtropical to tropical and humid regions, and altitudes above 3,900 meters above sea level. It is hardy and can grow well under moisture stress, but sandy loam is the most suitable soil. Quinoa grows rapidly, reaching heights of 2 meters, with alternating, coarsely serrated, triangular to ovate leaves.

Soil quality improvement and maintenance are crucial for enhancing agricultural production and India's food and nutritional security. To meet future demands, better planning and resource management are needed. Chemical or inorganic fertilizers are increasing in use, but they can lead to long-term effects like soil structure deterioration, soil health issues, and environmental pollution. The cost of chemical fertilizers is also increasing. Using organic manures alone as a replacement for inorganic fertilizers is not practical or economical, as it may not sustain current crop production levels and meet growing food demand. Combining organic manures with inorganic fertilizers can increase agricultural production and maintain soil health for longer periods(Gawai and Panwar, 2007). This approach offers farmers significant potential for increasing crop yield, maintaining soil fertility, and health.

Integrated Nutrient Management (INM) is a crucial approach to maintaining and improving soil properties(Albiach*et al*., 2000). It ensures a balanced supply of essential nutrients like nitrogen, phosphorus, and potassium, preventing imbalances that can harm soil health and plant growth. INM incorporates organic materials like compost and manure, enhancing soil fertility and building organic matter. It also addresses soil pH issues, ensuring nutrient availability and microbial activity. INM practices reduce soil degradation, erosion, and nutrient depletion, contributing to long-term soil property preservation. It minimizes nutrient losses, reducing water pollution and environmental damage. INM promotes soil resilience to climate change and supports sustainable agriculture.

In recent years, some farmers showing interest to grow this crop because of its nutrient content and climate resilience.Since very limited research has been done on this crop in our country, the study has been conducted to standardize the nutrient management practices in quinoa. At the same time due to more dependent on chemical fertilizers causing harmful effect on soil health. So, for sustainable agriculture practice of INM is important and this crop respond well to use of organic and biofertilizers from previous studies. In this context, an experiment wasdesigned to evaluate the influence of Integrated Nutrient Management on major nutrient status and physico-chemical properties of soil in Quinoa (*Chenopodium quinoa* Willd.).

2. Material and methods

A Field experiment was conducted in M- block, GKVK, Bengaluru. It is located at an altitude of 924 m above MSL at 13^0 09' North latitude and 77^0 57' East longitudes situated in the Eastern Dry Zone of Karnataka.During *rabi* 2022-23 with a test crop quinoa. The recommended dose of fertilizer (60:40:40,N, P_2O_5 and K_2O) applied as basal dose with recommended spacing of 45×15 cm. Randomized complete block design was used with 11 treatment and 3 replications. Table 1 provides the initial physical and chemical properties status of soil from experimental area. There are different types of organic manures like Farm Yard Manure (FYM), Vermicompost (VC) and Neem Cake (NC), biofertilizers like Azatobacter, Phosphorus Solubilizing Bacteria (PSB) for seed treatment and inorganic fertilizers like Urea, DAP, MOP has been used in the present investigationand the following are the treatment combinations.

T_1	100% Fertilizer dose
T_2	75% ND + 25% N through Farm yard manure (FYM)
T_3	75% ND + 25% N through Vermicompost (VC)
T_4	75% ND + 25% N through Neem cake (NC)
T_5	50% ND + 50% N through Farm yard manure (FYM)
T_6	50% ND + 50% N through Vermicompost (VC)
T_7	50% ND + 50% N through Neem cake (NC)
T_8	50% ND + 50% N through FYM + Seed treatment (Azotobacter + PSB)
T_9	50% ND + 50% N through VC + Seed treatment (Azotobacter + PSB)
T_{10}	50% ND + 50 % N through NC + Seed treatment (Azotobacter + PSB)
T_{11}	Absolute control

List 1. Treatment details of the experiment

Note:

ND=Nitrogen Dose

100%Fertilizer dose = 60:40:40 ($N:P_2O_5:K_2O$ kg ha^{-1}),7.5 tons FYM ha^{-1}

100% P_2O_5, K_2O and FYM common for all the treatments except for absolute control.

Table 1. Initial physico-chemical properties of the soil from the experimental site

Particular	Value	Method followed
A. Mechanical properties		
1. Sand %	53.08	International Pipette method (Piper, 1966)
2. Silt %	23.27	
3. Clay %	23.65	
4. Textural classes	Sandy Clay Loam	
5. Taxonomical class	*Typic haplustepts*	
5. Bulk density (Mg m^{-3})	1.41	Keen's cup method (Piper, 1966)
6. Maximum water holding capacity (%)	30.44	
B. Chemical properties		
1. Soil pH (1:2.5)	6.33	pH Meter (Jackson, 1973)
2. Electrical Conductivity (dSm^{-1}) at 25^{o}C (1:2.5)	0.24	EC meter (Jackson, 1973)
3. Organic Carbon (per cent)	0.46	Walkley and Black's method (1934)
4. Available N (kg ha^{-1})	294.52	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
5. Available P_2O_5 (kg ha^{-1})	26.86	Bray's method (Bray, 1945)
6. Available K_20 (kg ha^{-1})	151.62	Neutral normal NH_4OAC method (Page *et al.*1982)
7. Exchangeable Ca [c mol (p^{+}) kg^{-1}]	2.38	Versenate titration method (Jackson, 1973)
8. Exchangeable Mg c mol (p^{+}) kg^{-1}	1.46	Versenate titration method (Jackson, 1973)
9. Available S (mg kg^{-1})	13.72	Turbidometry extraction method (Black 1965)
14. Available B (mg kg^{-1})	0.32	Hot water-soluble extraction method (John *et al.*,1975)
10. DTPA extractable Fe (mg kg^{-1})	5.62	Atomic Absorption spectrophotometry (Lindsay and Norwell, 1978)
11. DTPA extractable Mn (mg kg^{-1})	3.00	
12. DTPA extractable Zn (mg kg^{-1})	0.56	
13. DTPA extractable Cu (mg kg^{-1})	0.66	

2.1 Collection of soil samples and methodology for soil analysis

Soil samples at a plough layer depth (0-15 cm depth) were obtained from each of the experimental site's thirty-three plots after the crop's harvest. The samples obtained were dried in shade, rendered with a pestle and motor to ground, passed through 2 mm sieve, and placed in polythene bags. The soil samples that were initially obtained are examined for different physical and chemical characteristics using standard techniques after quinoa harvest.

2.2Statistical analysis of data

The comparative study of experimentally collected results was carried out by implementing Fisher's system of measurement of variance as described by Panse and Sukhatme (1978).The significance level ($p<0.05$) used in the 'F' evaluation was offered at 5%. Critical difference (CD) values are presented at a significance level of 5%, wherever the 'F' measure was found to be relevant at 5%.

3. RESULTS AND DISCUSSION

3.1 Bulk Density (Mg m^{-3}) and Maximum Water Holding Capacity (MWHC) (%) status of soil after the harvest of quinoa.

The data presented in Table 2. pertains to the post-harvest maximum water holding capacity and bulk density of soil in relation to different integrated nutrient management practices applied during quinoa cultivation.

The recorded MWHC percentage of the soil after harvest ranged from 31.40% to 40.01%. The findings underscore the substantial influence of integrated nutrient management practices on the soil's MWHC. Notably, the MWHC varied among treatments employing diverse nutrient management strategies. In particular, treatment T_8 (50% ND + 50% N through FYM + seed treatment (Azotobacter + PSB)) exhibited the highest MWHC percentage at 40.01%in compare with treatment T_1 receiving 100% fertilizer dose, showed the less MWHC *i.e.*,32.30%.

On the other hand, bulk density of soil after harvest of quinoa crop were not significantly altered, though not significantly but bulk density of soil decreased positively with the increasing rate of use of organic manures over 100% inorganic fertilizer dose, while maximum water holding capacity had increased significantly in all the combinations of organic and inorganic treatments over 100% fertilizer dose.

Table 2. Effect of Integrated Nutrient Management on Bulk Density (Mg m^{-3}) and Maximum Water Holding Capacity (%) status of soil after the harvest of quinoa

	Treatments	Bulk Density	Maximum Water Holding Capacity
		Mg m^{-3}	%
	Initial	1.41	30.44
T_1	100 % Fertilizer dose	1.40	32.30
T_2	75 % ND + 25 % N through Farm yard manure (FYM)	1.38	37.94
T_3	75 % ND + 25 % N through Vermicompost (VC)	1.38	34.50
T_4	75 % ND + 25 % N through Neem cake (NC)	1.39	33.20
T_5	50 % ND + 50 % N through Farm yard manure (FYM)	1.36	39.48
T_6	50 % ND + 50 % N through Vermicompost (VC)	1.37	35.97
T_7	50 % ND + 50% N through Neem cake (NC)	1.37	34.90
T_8	50 % ND + 50 % N through FYM + Seed treatment (Azotobacter + PSB)	1.34	40.01
T_9	50 % ND+ 50 % N through VC + Seed treatment (Azotobacter + PSB)	1.35	36.91
T_{10}	50% ND + 50 % N through NC + Seed treatment (Azotobacter + PSB)	1.36	35.82
T_{11}	Absolute control	1.41	31.40
	SEm ±	**0.05**	**1.22**
	CD (P=0.05)	**NS**	**3.61**

Integrated Nutrient Management practices has had a significant ($p<0.05$) influence on the physical properties of soil *viz.,* maximum water holding capacity and recorded higher maximum water holding capacity values over the rest of treatments. This may be attributed to the organic matter provides more surface for absorption and adsorption of water molecules in micro and macro pores, respectively accordance with Birajdar*et al.* (2001).

3.2 pH and Electrical Conductivity (dS m^{-1}) of soil after the harvest of quinoa.

The results regarding soil pH following the harvest of quinoa crops under the influence of integrated nutrient management techniques is presented in Table 3. The dataset illustrates that the pH of the soil after harvest ranged from 6.09 to 6.43. The findings suggest that the integrated nutrient management practices did not exert a significant impact on soil pH. Nonetheless, the treatment T_8 (50% ND + 50% N through FYM + seed treatment (Azotobacter + PSB)) exhibited a numerically higher soil pH of 6.43 compared to treatment T_1, which received the full 100% fertilizer dose and recorded the lowest soil pH of 6.09.

The experimental results information regarding soil electrical conductivity (dSm^{-1}) subsequent to the quinoa crop harvest, influenced by integrated nutrient management practices, is outlined in Table 3. The data within Table 3. unambiguously demonstrate that the integrated nutrient management practices did not exert a significant impact on the electrical conductivity of the soil after harvest. Nevertheless, the treatment T_{11}, representing the absolute control, displayed the lowest numerical value for electrical conductivity (0.23 dSm^{-1}). This was in contrast to treatment T_1 (100% Fertilizer dose), which exhibited the highest electrical conductivity value (0.28 dSm^{-1}).

The data presented in Table 3. indicates that pH and EC in soil, after the harvest of quinoa crop were not significantly altered by integrated nutrient management practices. pH and EC of surface soil at harvest did not differ significantly over initial values as the duration of the crop is less, the basic soil properties like pH and EC will not change significantly by application of low quantities of manures and fertilizers. These results are in line with the findings of Arbad *et al.* (2008) in sweet sorghum and Divya *et al.* (2017) in pearl millet.

3.3 Soil Organic Carbon (%) of soil after the harvest of quinoa

Organic carbon levels (%) in the soil subjected to the integrated nutrient management practices after the quinoa harvest as detailed in Table 3. The dataset indicates a range of 0.45% to 0.59% for organic carbon content in the post-harvest soil. The findings highlight a significant impact of integrated nutrient management practices on the percentage of soil organic carbon across various treatments following the quinoa harvest. Remarkably, the treatment labelled as T_9 (50% ND + 50% N through vermicompost + Seed

Table 3. Effect of Integrated Nutrient Management on pH, Electrical Conductivity (dS m^{-1}) and Organic carbon (%) status of soil after the harvest of quinoa

	Treatments	**pH**	**Electrical Conductivity**	**Organic Carbon**
			dSm^{-1}	**%**
	Initial	6.33	0.24	0.46
T_1	100 % Fertilizer dose	6.09	0.28	0.48
T_2	75 % ND + 25 % N through Farm yard manure (FYM)	6.23	0.27	0.50
T_3	75 % ND + 25 % N through Vermicompost (VC)	6.22	0.27	0.52
T_4	75 % ND + 25 % N through Neem cake (NC)	6.22	0.26	0.49
T_5	50 % ND + 50 % N through Farm yard manure (FYM)	6.39	0.26	0.52
T_6	50 % ND + 50 % N through Vermicompost (VC)	6.39	0.25	0.57
T_7	50 % ND + 50% N through Neem cake (NC)	6.37	0.25	0.50
T_8	50 % ND + 50 % N through FYM + Seed treatment (Azotobacter + PSB)	6.43	0.26	0.55
T_9	50 % ND+ 50 % N through VC + Seed treatment (Azotobacter + PSB)	6.42	0.26	0.59
T_{10}	50% ND + 50 % N through NC + Seed treatment (Azotobacter + PSB)	6.41	0.25	0.54
T_{11}	Absolute control	6.30	0.23	0.45
	SEm ±	**0.22**	**0.19**	**0.02**
	CD (P=0.05)	**NS**	**NS**	**0.05**

treatment (Azotobacter + PSB)) recorded the highest organic carbon content at 0.59%in compare to the organic carbon content in treatment T_1 (100% fertilizer dose) which recorded value of 0.48%.

With the application of treatment T_9*i.e.*,50% ND + 50% N through vermicompost + seed treatment (Azotobacter + PSB) organic carbon content has significantly increased among the treatments. Because vermicompost being a completely decomposed it contributes more amount of carbon to soil and enhances the microbial activity which increases the decomposition rate of plant residue and improves the organic carbon content of the soil. These results were in accordance with Sahoo (2020).

3.4 Available Major Nutrients (kg ha^{-1}) Status of soil after the harvest of quinoa

Integrated nutrient management practices influence on available nitrogen, phosphorus and potassium (kg ha^{-1}) in soil after harvest of quinoa crop presented in Table 4. Among the treatments, significantly highest available nitrogen, phosphorus and potassium 361.79, 39.45 and 173.86 (kg ha^{-1}) noticed in treatment T_9 (50% ND + 50% N through vermicompost + Seed treatment (Azotobacter + PSB)), when compare to treatment T_1 (100% Fertilizer dose) was recorded significantly less available nitrogen (305.03, 30.53 and 145.66 kg ha^{-1}).

Table 4. Effect of Integrated Nutrient Management on available major nutrients (Nitrogen, Phosphorus and Potassium)(kg ha^{-1}) status of soil after the harvest of quinoa

	Treatments	**Available Nitrogen**	**Available Phosphorus**	**Available Potassium**
		kg ha^{-1}		
	Initial	294.52	26.86	151.62
T_1	100 % Fertilizer dose	305.03	30.53	145.66
T_2	75 % ND + 25 % N through Farm yard manure (FYM)	311.26	31.23	148.41
T_3	75 % ND + 25 % N through Vermicompost (VC)	320.34	32.07	154.89
T_4	75 % ND + 25 % N through Neem cake (NC)	315.51	31.86	152.04
T_5	50 % ND + 50 % N through Farm yard manure (FYM)	327.62	33.41	157.45
T_6	50 % ND + 50 % N through Vermicompost (VC)	340.44	35.15	162.86
T_7	50 % ND + 50% N through Neem cake (NC)	333.92	34.94	160.76
T_8	50 % ND + 50 % N through FYM + Seed treatment (Azotobacter + PSB)	348.53	35.89	166.72
T_9	50 % ND+ 50 % N through VC + Seed treatment (Azotobacter + PSB)	361.79	39.45	173.86
T_{10}	50% ND + 50 % N through NC + Seed treatment (Azotobacter + PSB)	354.86	37.67	170.45
T_{11}	Absolute control	282.87	23.76	140.79
	SEm ±	**11.49**	**1.19**	**5.52**
	CD (P=0.05)	**33.84**	**3.50**	**16.27**

Data showing available N, $P_2O_5$and K_2O of soil after the harvest of quinoa was presented in Table 4. It revealed that, available major nutrients were significantly influenced by different treatments.The greater accessibility of nitrogen might be attributed to the combination of added mineral fertilizer N and organic sources along with biofertilizers. This combination likely played a role in reducing the carbon-to-nitrogen (C:N) ratio, increasing microbial population thereby expediting the decomposition rate. As a result, nutrients from the manures became available more rapidly. This pattern of outcomes aligns with findings from studies conducted by Desai *et al*. (2013) and Negi (2017).

The increased availability of phosphorus could be attributed to the liberation of organic acids during the microbial breakdown of organic substances. These acids likely aided in making native phosphates more soluble, consequently boosting the accessibility of phosphorus. The introduction of organic matter might have facilitated the creation of a layer on the sesquioxide clay minerals, this coating could be the reason behind the diminished capacity of the soil to bind phosphates in plots treated with manure. Comparable outcomes were documented in studies conducted by Sahoo (2020) and Varalakshmi (2005).

The distribution of potassium between non-exchangeable and exchangeable forms is configured in a way that sustains potassium availability throughout the growth period. The positive impact of organic materials and higher microbial population on accessible potassium levels can be attributed to the reduction in potassium fixation and the subsequent release of potassium due to the interaction between organic matter and clay minerals. This interaction goes beyond direct potassium supplementation to the soil's potassium reservoir. (Desai *et al.*, 2013)

CONCLUSION

From the present study, it has been observed that integrated use of biofertilizers, organic manures and chemical fertilizers in combination at an appropriate resulted the best nutrient management practice among the eleven different treatments followed, improving the availability of soil major nutrient status and some of the physico- chemical properties after harvest of quinoa. Studiedthree different organic manures treatments along with inorganic among that vermicompost with seed treatment influence on soil properties more, it is concluded that quinoa is responsive to vermicompost as organic fertilizer that was highest effective when applied on sandy clay loam soil for improved soil properties, soil fertility and soil health management.

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