Mysore J. Agric. Sci., 58 (2) : 106-115 (2024)

Effect of Integrated Nutrient Management Practices on Growth and Yield of Quinoa (*Chenopodium quinoa* Willd.) in Sandy Clay Loam Soil

D. Bindu[1], B. Mamatha[2], S. R. Anand[3], B. Gayathri[4] and D. S. Rohitha[5]
[1,2,4&5]Department of Soil Science & Agricultural Chemistry, [3]Department of Agronomy,
College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : bindudpal35@gmail.com

Authors Contribution

D. Bindu : Conceptulization and conducting experiment;

B. Mamatha : Supervision and data analysis;

S. R. Anand & B. Gayathri : Data curation and data correction;

D. S. Rohitha : Data curation and supervision

Corresponding Author :
D. Bindu

Received : January 2024
Accepted : February 2024

Abstract

An experiment was conducted during the *rabi* 2022-23 season to investigate the effect of integrated nutrient management on growth and yield of quinoa. It was laid out in Randomized Block Design with three replications. Results revealed that application of different sources of manures either alone or in combination with fertilizer and biofertilizers application significantly affected the growth and yield of quinoa. Application of treatment 50 per cent nitrogen dose (ND) + 50 per cent N through vermicompost (VC) + seed treatment (Azotobacter + PSB) in comparison to application of 100 per cent fertilizer dose observed significantly higher plant height (134.85 cm), number of branches (24.56 plant^{-1}), dry matter production (23.82g plant^{-1}), leaf area (583.73 cm^2 plant^{-1}), panicle length (39.54 cm), harvest index (45.01), grain yield (1814.87 kg ha^{-1}) and stover yield (2217.13 kg ha^{-1}).

Keywords : Integrated nutrient management, Quinoa, Growth, Yield

Quinoa (*Chenopodium quinoa* Willd.), a nutritious pseudo-cereal, is an annual herbaceous plant from the Amaranthaceae family, quinoa was first discovered by North Americans and Europeans as a nutritious diet in the 1970s, because it is gluten-free (useful for diabetic patients), high in protein and amino acids, since then, its popularity has grown tremendously. According to Simmonds (1971), quinoa is more flexible in its ability to respond to photo period, altitude, soil pH, etc. It is a perennial plant with broad leaves that can adapt to the circumstances of marginal areas (Rea *et al*., 1979). Quinoa is a chene that ranges in color from white or light yellow to orange, red, brown and black, with deep, penetrating roots, these plants can reach heights of 1-2 meters. It contains Ca, Fe, Zn, Cu and Mn and has an oil content of 1.8 to 9.5 per cent. 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.

Better resource management and planning are required to satisfy future needs. In order to increase agricultural productivity and India's food and nutritional security, soil quality must be improved and maintained. Although the use of chemical or inorganic fertilizers is increasing, they can have long-term consequences such as loss of soil structure, problems with soil health and environmental contamination. Chemical fertilizers are becoming more expensive as well. It is not possible nor cost-effective to use organic manures alone to replace chemical fertilizers since they might not be able to maintain present crop output levels and satisfy rising food demand. Agriculture productivity may be increased and soil health can be preserved for longer periods of time by combining organic manures with inorganic fertilizers (Gawai and Panwar, 2007).

With this strategy, farmers have a significant chance to increase crop output, preserve soil fertility and health.

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.

Integrated Nutrient Management (INM) is crucial for quinoa cultivation as it optimizes nutrient availability, maintains balanced uptake, reduces nutrient losses, enhances soil health and boosts crop resilience and quality. INM incorporates organic materials, which enhance soil structure, increase water-holding capacity and promote beneficial microbial activity. Healthy soils result in better root development and nutrient absorption by plants. INM practices lead to increased crop yields, better grain quality and improved economic returns for farmers. Additionally, INM is adaptable to various environmental conditions, making it a versatile and sustainable approach for quinoa production worldwide.

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 was designed to evaluate the effect of Integrated Nutrient Management practices on growth and yield of Quinoa (*Chenopodium quinoa* Willd.).

Material and Methods

A Field experiment was conducted in M-block, GKVK, Bengaluru. It is located at an altitude of 924m 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 replication. 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 investigation and the following are the treatment combinations.

Treatments details

T1	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

Note : ND = Nitrogen Dose 100 per cent; Fertilizer dose = 60:40:40 (N: P_2O_5: K_2O kg ha^{-1}), 7.5 tons FYM ha^{-1} 100 per cent 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		
Sand %	53.08	International Pipette method (Piper, 1966)
Silt %	23.27	
Clay %	23.65	
Textural classes	Sandy Clay Loam	
Taxonomical class	*Typic haplustepts*	
Bulk density (Mg m^{-3})	1.41	Keen's cup method (Piper, 1966)
Maximum water holding capacity (%)	30.44	
B. Chemical properties		
Soil pH (1:2.5)	6.33	pH Meter (Jackson, 1973)
Electrical Conductivity (dSm^{-1}) at 25°C (1:2.5)	0.24	EC meter (Jackson, 1973)
Organic Carbon (per cent)	0.46	Walkley and Black's method (1934)
Available N (kg ha^{-1})	294.52	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	26.86	Bray's method (Bray, 1945)
Available K_20 (kg ha^{-1})	151.62	Neutral normal NH_4OAC method (Page *et al.,* 1982)
Exchangeable Ca [c mol (p^+) kg^{-1}]	2.38	Versenate titration method (Jackson, 1973)
Exchangeable Mg c mol (p^+) kg^{-1}	1.46	Versenate titration method (Jackson, 1973)
Available S (mg kg^{-1})	13.72	Turbidometry extraction method (Black, 1965)
Available B (mg kg^{-1})	0.32	Hot water-soluble extraction method (John *et al.,* 1975)
DTPA extractable Fe (mg kg^{-1})	5.62	Atomic Absorption spectrophotometry (Lindsay and Norwell, 1978)
DTPA extractable Mn (mg kg^{-1})	3.00	
DTPA extractable Zn (mg kg^{-1})	0.56	
DTPA extractable Cu (mg kg^{-1})	0.66	

Studies on Growth Attributes of Quinoa

The plant height, leaf area per plant and dry matter production per plant was estimated at 30 DAS, 60 DAS and at the harvest by tagging randomly selected five plants. The mean plant height, was worked out and expressed in centimetres (cm) at all these growth stages. From the five separate plants picked at random and tagged initially, the number of branches per plant was counted at all growth stages and the average number of branches per plant was documented. Leaf area was measured at 30, 60 and at harvest for randomly collected five plants using LI 3000 portable area meter (LICOR model) with transparent conveyor belt utilizing an electronic digital display. The excised leaves were fed in to conveyor belt assembly and average leaf area was worked out, recorded and expressed cm^2. Three plants were selected at random from border rows in each plot. The plants uprooted, air dried initially and then oven dried at 65°C till constant weight was obtained and their weights were recorded. Dry mater production was recorded at 30, 60 DAS and at harvest and expressed as g $plant^{-1}$.

Studies on Yield Attributes of Quinoa

The total length of panicles from each tagged plant in each plot was measured, averaged and expressed as cm. Grain yield obtained from each net plot including the tagged plants were sun dried, threshed manually, cleaned and weight was recorded using net plot yield treatment wise then converted to hectare and then seed yield expressed in kg ha^{-1}. Stover yield obtained from each net plot including the tagged plants were sun dried and weighed treatment wise then converted to hectare and expressed as q ha^{-1}. Harvest index used to quantify the yield of a crop species versus the total amount of biomass that has been produced. From the obtained grain and stover yield, harvest index was deduced and expressed in numbers.

Statistical 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 per cent. Critical difference (CD) values are presented at a significance level of 5 per cent, wherever the 'F' measure was found to be relevant at 5 per cent.

Results and Discussion

Effect of Integrated Nutrient Management Practices on Growth of Quinoa

Fig. 1, Table 2 and 3 present's data on plant height (cm), number of branches dry matter production (g $plant^{-1)}$ and leaf area (g $plant^{-1}$) as influenced by integrated nutrient management practices at different growth stages.

With different treatments, plant height varied greatly at all growth stages, at 30 DAS, the plant height was recorded non-significant among different integrated nutrient management practices. However, numerically higher plant height (37.00 cm) was recorded with application of 50 per cent ND + 50 per cent N through vermicompost + seed treatment (Azotobacter + PSB) (T_9) when compare to treatment T_1 (30.43 cm) which received 100 per cent fertilizer dose. Whereas, lower plant height (26.17 cm) was recorded in absolute control (T_{11}). Whereas significantly higher plant height 124.65 cm at 60 DAS and 134.85 cm at harvest was recorded, these results were comparable to treatment T_1 which received 100 per cent fertilizer dose was recorded lesser plant height (110.54 cm at 60 DAS and 118.63 cm at harvest). Lowest value was reported in absolute control which did not obtain any external nutrient sources.

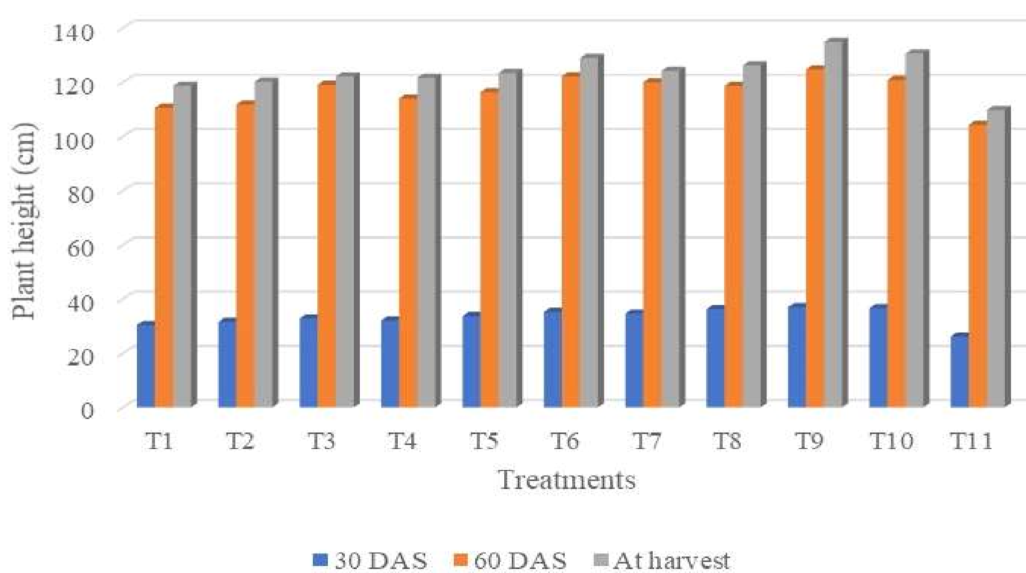

Fig. 1 : Effect of Integrated Nutrient Management on plant height (cm) of quinoa at 30 DAS, 60 DAS and at harvest stage

TABLE 2
Effect of integrated nutrient management on number of branches (plant^{-1}) of quinoa at 30 DAS, 60 DAS and harvest stage

Treatments	Number of branches (plant^{-1})		
	30 DAS	60 DAS	At harvest
T_1 - 100% Fertilizer dose	13.24	18.60	16.74
T_2 - 75% ND + 25% N through Farm yard manure (FYM)	13.37	19.81	17.31
T_3 - 75% ND + 25% N through Vermicompost (VC)	13.46	21.34	18.42
T_4 - 75% ND + 25% N through Neem cake (NC)	13.42	20.57	17.86
T_5 - 50% ND + 50% N through Farm yard manure (FYM)	13.48	21.74	18.67
T_6 - 50% ND + 50% N through Vermicompost (VC)	13.53	22.80	20.43
T_7 - 50% ND + 50% N through Neem cake (NC)	13.50	22.20	19.92
T_8 - 50% ND + 50% N through FYM + Seed treatment (Azotobacter + PSB)	13.54	23.43	21.13
T_9 - 50% ND + 50% N through VC + Seed treatment (Azotobacter + PSB)	13.98	24.56	22.81
T_{10} - 50% ND + 50 % N through NC + Seed treatment (Azotobacter + PSB)	13.54	24.20	21.26
T_{11} - Absolute control	13.04	17.23	14.26
SEm ±	0.46	0.76	0.68
CD (P=0.05)	NS	2.25	2.00

TABLE 3
Effect of integrated nutrient management on dry matter production (g plant^{-1}) of quinoa at 30 DAS, 60 DAS and at harvest stage

Treatments	Dry matter (g plant^{-1})		
	30 DAS	60 DAS	At harvest
T_1 - 100% Fertilizer dose	5.42	14.90	19.23
T_2 - 75% ND + 25% N through Farm yard manure (FYM)	5.67	15.34	20.50
T_3 - 75% ND + 25% N through Vermicompost (VC)	5.87	16.10	21.17
T_4 - 75% ND + 25% N through Neem cake (NC)	5.72	15.82	20.97
T_5 - 50% ND + 50% N through Farm yard manure (FYM)	5.88	16.57	21.50
T_6 - 50% ND + 50% N through Vermicompost (VC)	5.98	17.48	22.60
T_7 - 50% ND + 50% N through Neem cake (NC)	5.91	16.90	22.23
T_8 - 50% ND + 50% N through FYM + Seed treatment (Azotobacter + PSB)	5.98	17.60	23.00
T_9 - 50% ND + 50% N through VC + Seed treatment (Azotobacter + PSB)	6.24	18.68	23.82
T_{10} - 50% ND + 50 % N through NC + Seed treatment (Azotobacter + PSB)	6.18	18.20	23.50
T_{11} - Absolute control	5.37	13.82	17.65
SEm ±	0.20	0.58	0.76
CD (P=0.05)	NS	1.71	2.23

Number of branches per plant as influenced by integrated nutrient management practices are presented in Table 2. At 30 DAS, branches per plant were recorded and showed non-significant among different Integrated Nutrient Management practices. At 60 DAS significantly, more branches (24.56 plant^{-1}) were recorded with application of 50 per cent ND + 50 per cent N through vermicompost + seed treatment (Azotobacter + PSB) (T_9) over treatment T_1 (100% Fertilizer dose) which recorded 18.60 plant^{-1}.

At harvest, number of branches per plant was significantly influenced by different Integrated Nutrient Management practices. More branches (22.81 plant^{-1}) were recorded with application of 50 per cent ND + 50 per cent N through vermicompost + seed treatment (Azotobacter + PSB) (T_9) when compare to treatment T_1 (100 % Fertilizer dose) which recorded 16.74 plant^{-1}. However, the smaller number of branches (14.26 plant^{-1}) was recorded in absolute control.

A similar kind of trend was observed in case of dry matter production (6.24 at 30 DAS, 18.68 at 60 DAS and 23.82 at harvest) g plant^{-1} and leaf area (329.75 at 30 DAS, 583.73 at 60 DAS and 546.78 at harvest) per plant as well.

Due to application of 50 per cent ND + 50 per cent N through vermicompost + seed treatment (Azotobacter + PSB) (T_9), significant increase in growth parameters such as plant height, number branches, dry matter production and leaf area was reported. Significantly higher plant height of quinoa recorded due to the availability of nutrients through organic and inorganic sources in sufficient quantity with effective microbes in biofertilizers that creates the favourable environment for plant growth which enhances the growth and yield parameters. (Neeraja and Patel, 2015). Organic manures had a major role in supply of all vital nutrients required by the plants. Nitrogen being the growth nutrient is reported to increase the branches numbers. In the present investigation integrated use of manures and fertilizers had improved the plant growth parameters compared to application manures and fertilizers alone. These results with the findings of Monisha *et al.* (2019). The total dry matter of quinoa crop increased significantly this might be due to the established fact that vermicompost improves the physical and biological properties of soil including supply of almost all the essential plant nutrients for the growth and development of plants. Balanced nutrition due to release of macro and micro nutrients by microbial decomposition on vermicompost under favourable environment might have helped in higher uptake of the nutrients. This accelerated the formation of new tissues and development of new shoots that have ultimately increased the total dry matter accumulation. The results of present investigation are in line with those of Bairwa *et al.,* 2013 and Duryodhana *et al*., 2004. Increased leaf area was mainly due to higher nutrient uptake and leaf area duration towards reproductive stage due to application of organic source of nutrients as also been documented by Ramachandra and Timmaraju (1983).

Effect of Integrated Nutrient Management Practices on Yield of Quinoa

Fig. 2, represents the data on grain yield and stover yield as influenced by integrated nutrient management practices after the harvest of quinoa.

Grain and stover yield of quinoa due to different integrated nutrient management practices were found significant. Among the treatments, treatment receiving soil application of 50 per cent ND + 50 per cent N through vermicompost + seed treatment (Azotobacter + PSB) recorded higher grain yield (1814.87 kg ha^{-1}) over treatment T_1 which received 100 per cent fertilizer dose (1393.48 kg ha^{-1}). Similarly, in case of stover yield among the treatments, application of 50 per cent ND + 50 per cent N through vermicompost + seed treatment (Azotobacter + PSB) recorded significantly higher stover yield (2217.13 kg ha^{-1}) when compare to treatment T_1 which received 100 per cent fertilizer dose (1829.22 kg ha^{-1}). Absolute control (T_1) recorded significantly lower grain and stover yield (810.69 and 1112.23 kg ha^{-1}).

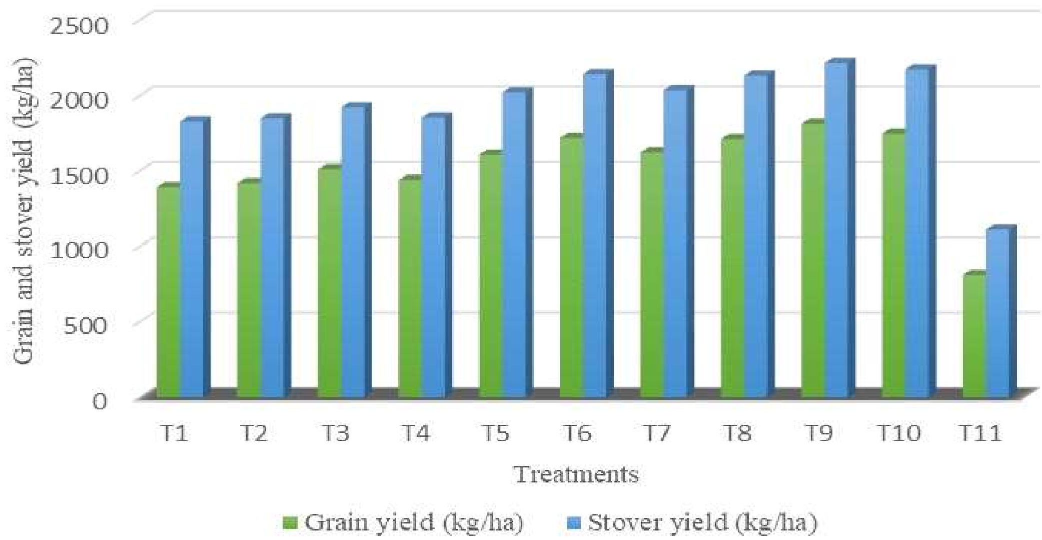

Fig. 2 : Effect of Integrated Nutrient Management on grain yield and stover yield (kg ha^{-1}) of quinoa

Significantly grain and stover yield of quinoa recorded in treatment T_9 (50% ND + 50% N through vermicompost + Seed treatment (Azotobacter + PSB) due to the availability of nutrients through organic and inorganic sources in sufficient quantity with effective microbes in biofertilizers that creates the favourable environment for plant growth which enhances the growth and yield parameters (Neeraja and Patel, 2015). Actually, addition of vermicompost in soil before sowing has immediate benefit as it contain nutrients in plant available form and these nutrients can be directly absorbed by the crop plants,

TABLE 4

Effect of integrated nutrient management on leaf area per plant of quinoa at 30 DAS, 60 DAS and harvest stage

Treatments	Leaf area (cm^2 plant^{-1})		
	30 DAS	60 DAS	At harvest
T_1 - 100% Fertilizer dose	316.78	436.36	417.95
T_2 - 75% ND + 25% N through Farm yard manure (FYM)	319.12	449.98	426.37
T_3 - 75% ND + 25% N through Vermicompost (VC)	320.15	478.39	446.71
T_4 - 75% ND + 25% N through Neem cake (NC)	319.26	457.33	433.66
T_5 - 50% ND + 50% N through Farm yard manure (FYM)	321.54	482.41	453.74
T_6 - 50% ND + 50% N through Vermicompost (VC)	325.17	537.28	487.56
T_7 - 50% ND + 50% N through Neem cake (NC)	322.32	486.84	465.89
T_8 - 50% ND + 50% N through FYM + Seed treatment (Azotobacter + PSB)	323.47	546.57	507.80
T_9 - 50% ND + 50% N through VC + Seed treatment (Azotobacter + PSB)	329.75	583.73	546.78
T_{10} - 50% ND + 50 % N through NC + Seed treatment (Azotobacter + PSB)	325.43	547.96	518.45
T_{11} - Absolute control	311.86	403.53	388.69
SEm ±	11.06	17.41	16.41
CD (P=0.05)	NS	51.37	48.39

referred by Arbad *et al*. (2008). Higher yield due to combined application of chemical fertilizers and organic manures might have attributed to sustained nutrient supply and also as a result of better utilization of applied nutrients through improved micro environmental conditions, especially the activities of soil microorganisms involved in nutrient transformation and fixation. These findings are in close agreement with those reported by Senapati *et al*. (2007).

Panicle length and harvest index as influenced by integrated nutrient management practices are presented in Table 3. Panicle length was significantly influenced by different integrated nutrient management practices. Significantly higher panicle length (39.54 cm) was recorded with treatment imposed by 50 per cent ND + 50 per cent N through vermicompost + seed treatment (Azotobacter + PSB) over treatment T_1 which received 100 per cent fertilizer dose (30.01 cm) and significantly lower panicle length (29.08 cm) was recorded in absolute control.

Harvest index of quinoa due to different INM practices were found to be non-significant. However, application of 50 per cent ND + 50 per cent N through vermicompost + seed treatment (Azotobacter + PSB) recorded numerically highest *i.e*., 44.55, when compare to treatment T_1 which received 100 per cent fertilizer dose which recorded 43.69. The lower harvest indices were recorded with treatment absolute control (42.16).

The significant increase in panicle length could be attributed to the supply of recommended dose of nitrogen through the combined application of chemical and organic sources, which helped in boosting the growth due to increase in photosynthesis and better transfer of assimilates. This result agreed with the findings of Parmar and Patel (2009) and Sing and Yadav (2004). This might be due to more vigorous and luxuriant vegetative growth due to application of vermicompost along with inorganic fertilizer, which in turn favoured a better partitioning of assimilates from source to sink. The present results were in accordance with the findings of Subramanian and Ganesaraja (1992) and Hasan *et al*. (2013).

The study demonstrated that the effect of integrated nutrient management practices on growth and yield of quinoa. Integrated use of biofertilizers, organic

TABLE 5

Effect of integrated nutrient management on panicle length (cm) and harvest index of quinoa

Treatments	Panicle length (cm)	Harvest index
T_1 - 100% Fertilizer dose	30.01	43.69
T_2 - 75% ND + 25% N through Farm yard manure (FYM)	31.98	43.42
T_3 - 75% ND + 25% N through Vermicompost (VC)	33.32	44.01
T_4 - 75% ND + 25% N through Neem cake (NC)	32.56	43.70
T_5 - 50% ND + 50% N through Farm yard manure (FYM)	34.11	44.30
T_6 - 50% ND + 50% N through Vermicompost (VC)	36.28	44.50
T_7 - 50% ND + 50% N through Neem cake (NC)	34.87	44.34
T_8 - 50% ND + 50% N through FYM + Seed treatment (Azotobacter + PSB)	37.12	44.53
T_9 - 50% ND + 50% N through VC + Seed treatment (Azotobacter + PSB)	39.54	45.01
T_{10} - 50% ND + 50 % N through NC + Seed treatment (Azotobacter + PSB)	39.02	44.55
T_{11} - Absolute control	29.08	42.16
SEm ±	1.22	1.52
CD (P=0.05)	3.59	NS

manures and chemical fertilizers in combination at an appropriate time significantly affects the growth and yield of quinoa. Studied three different organic manures treatments along with inorganic among that vermicompost with seed treatment influence more on growth and yield of quinoa. 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 in turn increases growth and yield of crop.

References

Albiach, R., Canet, R., Pomares, F. and Ingelmo, 2000, Microbial biomass content and enzymatic activities after the application of organic amendments to a horticultural soil. *Bioresour. Technol*., **75** (2) : 43 - 48.

Arbad, B. K., Syed, I., Shinde D. N. and Pardeshi, R., 2008, Effect of integrated nutrient management practices on soil properties and yield in sweet sorghum [*Sorghum biocolor* (L.) Moench] in vertisol. *Asian. J. Soil Sci*., **3** (2) : 329 - 332.

Bairwa, K., Dahiya, R., Kumar, P. and Phogagt, V. K., 2013, Effect of long term integrated nutrient management on soil properties, soil fertility, nutrient uptake and crop yields under pearl millet-wheat cropping system. *Res. on Crop*, **14** (3) : 762 - 768.

Bhargava, A., Sudhir, S. and Deepak, O., 2006, Quinoa (*Chenopodium quinoa* Willd.). An Indian perspective. *Ind. Crops Prod*., **23** (1) : 73 - 87.

Black, C. A., 1965, Methods of soil analysis part-1 physical and mineralogical properties. Agronomy Monograph No. 9. *American Soc. Agron. Madison,* Wisconsin, USA, **7** : 18 - 25.

Bray, R. H. and Kurtz, L. T., 1945, Determination of total, organic and available forms of phosphorus in soils. *Soil Sci.,* **59** (1) : 39 - 46.

Duryodhana, D., Gowda, G. K. T., Kadalli, G. G. and Ashok, E. G., 2004, Uptake pattern of major nutrients at different growth stages by dryland finger millet (*Eleusine coracana* L. Gaertn.) from different sources and levels of nutrients. *Mysore J. Agric. Sci*., **38** (4) : 487 - 495.

Gawai, P. P. and Panwar, V. S., 2007, Nutrient balance under RDMS sorghum-chickpea cropping sequence. *Indian J. Agric. Sci*., **41** (2) : 137 - 41.

Hasan, J., Crawford, R. J. and Ivanova, E. P., 2013, Antibacterial surfaces: the quest for a new generation of biomaterials. *Trends Biotechnol.*, **31** (5) : 295 - 304.

Jackson, M. L., 1973, *Soil chemical analysis*. Prentice Hall of India, New Delhi, **1** : 485 - 486.

John, H., Lindsay, B. U., Sawada, Y., 1975, Assessment of plant-available boron in some New Zealand soils. *J. Agricul. Res*., **26** (2) : 191 - 195.

Lindsay, W. L. and Norwell, W. A., 1978, Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. Amer. J*., **42** : 421 - 428.

Monisha, V., Rathinaswamy, A., Mahendran, P. P. and Kumutha, K., 2019, Influence of integrated nutrient management on growth attributes and yield of foxtail millet in red soil. *Int. J. Chem. Stud.,* **7** (3) : 3536 - 3539.

Neeraja, C. R. and Patel, M. V., 2015, Integrated nutrient management in Grain Amaranth (*Amaranthus hypochondriacus* L.) under Middle Gujarat conditions. *Indian J. Agric. Res*., **7** (1) : 57 - 61.

Page, A. L, Miller, R. H. and Kenay, D. R., 1982, *Methods of soil analysis, part - 2, Soil Science Society of America*, Inc, Publishers, Madison, Wisconsin, USA.

Panse, V. C. and Sukhatme, P. V., 1978, Statistical methods for agricultural workers. *III Rev.* New Delhi : ICAR.

Parmar, J. K. and Patel, J. J., 2009, Effect of organic and inorganic nitrogen and biofertilizer on nutrient content and uptake by amaranthus (*Amaranthus hypochondriacus* L.). *Asian J. Soil Sci*., **4** (1) : 135 - 138.

Piper, C. S., 1966, *Soil and plant analysis*, Hans Pub: Bombay, **7** : 368 - 369.

RAMACHANDRA, H. A. AND THIMMARAJU, K. R., 1983, Effect of different levels of nitrogen and phosphorus on nutrient status of grain amaranth (*Amaranthus gangaticus* L.). *Mysore J. Agric. Sci*., **17** (3) : 256 - 259.

REA, J., TAPIA, M., MUJICA, A., GANDARILLAS, H., ALANDIA, S. AND CARDOZO, A., 1979, Practicas agronomicas. In: Quinoa Kaniwa, *Cultivos Andinos., FAO, Rome*, Italy : 83 - 120.

SENAPATI, H. K., BANDDITA, J. AND DASH, A. K., 2007, Effect of vermicompost on ragi-tomato cropping systems. *Environ. Ecol*., **25** (3) : 648 - 650.

SIMMONDS, N. W., 1971, The breeding system of *Chenopodium quinoa*. *Male Sterility, Heredity*, **27** : 73 - 82.

SINGH, R. K. AND YADAV, B. S., 2004, Effect of vermi compost on productivity of gram (*Cicer arientinum*) and soil fertility. *Indian J. Agril. Sci*., **77** (11) : 613 - 615.

SUBBAIAH, A. Y. AND ASIJA, G. K., 1956, A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.,* **25** : 270 - 280.

SUBRAMANIAN, P. AND GANESARAJA, V., 1992, Response of *Setaria italica* to different management practices under dryland farming. *Ann. Arid Zone India*., **31** : 269 - 269.

WALKLEY, A. J. AND BLACK, I. A., 1934, An examination of wet acid method for determining soil organic matter and proposed modification of chromic acid titration method. *J. Soil Sci*., **37** : 29 - 38.