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Impact of organic and inorganic nutrient sources on growth parameters of apple (*Malus* × *domestica* Borkh) cv. Red Chief

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Abstract
The present study entitled "Impact of Organic and Inorganic Nutrient Sources on Growth Parameters of Apple (*Malus* × *domestica* Borkh) cv. Red Chief" was carried out during 2021-2022, in the experimental field of Division of Fruit Science, SKUAST-K on four year old apple plants cv. Red chief grafted on M_9 rootstock planted at a distance of 3 m× 1m trained on tall spindle system. The experiment was laid out in Randomized Block Design (factorial) comprised of 30 treatment combinations involving two sources of nutrients in which soil application (10 levels) and foliar (3 levels). Each treatment combination were replicated thrice. All other cultural practices were performed uniformly. The control treatment (S_0) represented the recommended fertilizer dose (185 g N + 100 g P + 240 g K). S_1:(30% NPK + 70% FYM + Bioinnoculants + Wood ash), S_2: (50% NPK + 50% FYM + Bioinoculants + Wood ash), S_3: (70% NPK + 30% FYM + Bioinoculants + Wood ash), S_4: (30% NPK + 70% Vermicompost + Bioinoculants + Wood ash), S_5: (50% NPK + 50% Vermicompost + Bioinoculants + Wood ash), S_6: (70% NPK + 30% Vermicompost + Bioinoculants + Wood ash), S_7: (50% FYM + 50% Vermicompost + Bioinoculants + Wood ash), S_8: (100% FYM + Bioinoculants + Wood ash), S_9: (100% Vermicompost + Bioinoculants + Wood ash). Foliar application F_0: [Ca (0.3%) + B (0.15%) + Zn (0.5%) + K (1.5%)] acted as control and F_1: [Ca (0.2%) + B (0.1%) + Zn (0.4%) + K (1.4%)], F_2:Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%). it was concluded that the integrated use of 70% NPK + 30% (Vermicompost + Bionoculants + Wood ash) along with the foliar application of Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%) is recommended for growers seeking improved growth characteristics of the plant. These findings contribute to the knowledge base of sustainable horticultural practices and serve as a valuable resource for apple growers and researchers, aiding in the development of targeted nutrient management strategies that maximize yield potential and ensure the production of high-quality apples.

Keywords: Organic, inorganic nutrient sources, growth parameters, *Malus* × *domestica* Borkh

Introduction
Apple (*Malus* × *domestica* Borkh.) is a temperate fruit crop and is grown in temperate regions of the world. Globally China ranks first in the production of apple whereas, India ranks fifth in the production of apple. In India apple is mainly grown in Jammu and Kashmir, Himachal Pradesh and Uttarakhand on an overall area of 314 thousand hectares with a production of 2503 MT (Anonymous, 2020a) [2]. Jammu and Kashmir has already established a unique position in the apple trade on a global scale. Apples forms the backbone of our state's economy, it is important to have high-yielding, high-quality fruits that can be stored for a long time, consistently bear fruit, that are free of diseases and pests. Chemical fertilizers have played a very significant role in providing nutrients for intensive crop production, increases the plant growth and vigour, but the plants grown in this way does not develop good plant characters such as, good root system, shoot system, nutritional characters. High density concept of orcharding was given thrust in India for wide adoption of improved apple cultivars specifically spurs types on clonal rootstocks. Orchard nutrition management for the high density plantations of spur type cultivars based on farmer's friendly integrated nutrient combinations is very much beneficial. Hence, use of chemical fertilization combined with organic fertilization or use of balanced organic fertilization may be a useful alternative to meet the nutrient demand of the crop in an eco-friendly manner and also to retain the physical, chemical and biological properties of the soil without any loss. As a result, several organic and biological sources have emerged as viable supplementary sources of inorganic fertilizers in

crop nutrition programme. Use of organic manures has been recognized as the most efficient practice for stimulation of various biological transformations in the soil, leading to soil fertility and health. Application of organic manures to soil not only improve soil physical properties, pH, water holding capacity but also add important nutrients to the soil, thus increase the nutrient availability (Das *et al.*, 2016) [6]. Integrated nutrient management plays a significant role in achieving the sustainable fruit production without interfering with the fertility. It is a system that helps to restore and sustain crop productivity, and also assists in checking the emerging micro-nutrient deficiencies (Dolker *et al.*, 2017) [7]. The use of green manures such as vermicompost, FYM, in combination with chemical fertilizers has resulted in the preservation of soil's physical, chemical, and biological qualities Korwar *et al.* (2005) [12]. An integrated nutritional management programme in principle is based on judicious and balanced supply of need based nutrient from organic and inorganic sources. Organic manures in sufficient quantities not only supplement NPK requirement from inorganic fertilizer sources, but also reduce the total quantity of inorganic fertilizers required as per fertilizer schedule. Integrated application of organic manures and inorganic fertilizers enhances overall performance of apple trees in terms of plant growth, yield and fruit quality and also facilitates better availability of nutrients like N, P, K, Ca, Mg and B for enhancing fruit yield and quality without any negative effect (Kumar *et al.*, 2017) [13]. Keeping in view the above facts, the present research was conducted with the objective of assessing then effect of organic and inorganic nutrient sources on the growth parameters of apple (*Malus* × *domestica* Borkh) cv. Red Chief.

Materials and Methods

The experiment was carried out at Experimental farm of Division of Fruit Science, SKUAST Shalimar Kashmir on four year old apple plants cv. Red chief at a spacing of 3 m× 1m. Four year old trees of exotic apple cv. "Red Chief" grafted on M-9 rootstock introduced by SKUAST-Kashmir from Holland in March 2017 were selected for experimentation. The 30 treatment combinations will be replicated thrice in Randomized Block Design (Factorial). The treatment combinations involved nutrient application through soil and via foliar means. The details of soil and foliar nutrient treatments are given below:

Soil Application

Treatment	Treatment notation
S_0 (Control):	N% + P% + K% as recommended = 185 g N+ 100 g P+ 240 g K = 363 g Urea + 217 g DAP + 400 g MOP
S_1:	30% NPK + 70% FYM + Bioinnoculants + Wood ash 55.5 g N + 30 g P + 72 g K + 25.9 kg FYM +Bioinoculants + 1.2 kgWood ash 108.3 g Urea + 65 g DAP + 120 g MOP
S_2:	50% NPK + 50%FYM + Bioinoculants + Wood ash 93 g N + 50 g P + 120 g K + 18.6 kg FYM + Bioinoculants + 900 g Wood ash 182.5 g Urea + 108 g DAP + 200 g MOP
S_3:	70% NPK + 30% FYM + Bioinoculants + Wood ash 129.5 g N + 70 g P + 168 g K + 11kg FYM + Bioinoculants + 566 g Wood ash 253.6 g Urea + 152 g DAP + 280 g MOP
S_4:	30% NPK + 70%Vermicompost + Bioinoculants + Wood ash 55.5 g N + 30 g P + 72 g K + 8.6 kg Vermicompost+ Bioinoculants +900 g Wood ash 108.3 g Urea + 65 g DAP + 120 g MOP
S_5:	50% NPK + 50% Vermicompost + Bioinoculants + Wood ash 93 g N+ 50 g P + 120 g K+ 6.2 kgVermicompost+ Bioinoculants + 300 g Wood ash 182.5 g Urea + 108 g DAP + 200 g MOP
S_6:	70% NPK + 30% Vermicompost + Bioinoculants + Wood ash 129.5 g N + 70 g P +168 g K+3.7 kg Vermicompost + Bioinoculants + 366 g Wood ash 253.6 g Urea + 152 g DAP + 280 g MOP
S_7:	50% FYM + 50% Vermicompost + Bioinoculants + Wood ash FYM 18.6 kg + 6.2 kgVermicompost + Bioinoculants + 600 g Wood ash
S_8:	100% FYM + Bioinoculants + Wood ash FYM 37 kg + Bioinoculants +1.8 kg Wood ash
S_9:	100% Vermicompost + Bioinoculants + Wood ash Vermicompost 12 kg + Bioinoculants + 1.4 kg Wood ash

Foliar Application

Treatment	**Treatment combination**
F0	Ca (0.3%) + B (0.15%) + Zn (0.5%) + K (1.5%)
F1	Ca (0.2%) + B (0.1%) + Zn (0.4%) + K (1.4%)
F2	Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%)

Calcium chloride spray was done thrice: 21 days after petal fall, 21 days after first spray and 30 days before harvest. Boric acid spray was done twice: 1st spray at pink bud stage and 2nd spray 21 days after petal fall. Zinc spray in the form of Zinc sulphate was done twice; at pink bud and at petal fall. Potassium spray in the form of potassium sulphate was done twice: 1st at petal fall and 2nd spray 21 days interval during fruit development.

The effect of various soil and foliar nutrient application treatments was assessed on various growth parameters such as plant height, girth and spread increment; annual shoot growth extension and leaf area. The incremental plant height, girth (15 cm above the graft uion) and spread (both North-South and East-West) was measured using measuring tape at the end of the growing season. Current season shoot growth was measured with the help of measuring tape at the end of growing season and expressed in centimetres (cm). Leaf area of each sample of twenty five leaves taken from middle shoots of current season growth was measured per plant basis with the help of Systronics leaf area metre 211 and average leaf area expressed in cm^2.

Results and Discussion

It is clear from the data presented in Table-1, plant height increment was significantly influenced when the plants were treated with combined application of soil and foliar nutrient sources during both the years of investigation. During 2021 maximum plant height increment (33.03 cm) was observed in treatment combination **(**50% NPK + 50% Vermicompost + Bioinoculants + Wood ash) S_5F_2 along with the foliar application of Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%) and minimum plant height increment (15.20 cm) was observed in treatment combination **(**100% FYM + Bioinoculants + Wood ash) S_8F_1 along with the foliar application of Ca (0.2%) + B (0.1%) + Zn (0.4%) + K (1.4%). During 2022 highest (35.12 cm) was observed in treatment combination S_5F_2, which was statistically at par with S_5F_0, while lowest (16.21 cm) was observed in treatment combination S_8F_1. Similar pattern was followed for the pooled data over both the years. Pooled data showed maximum plant height increment (34.08 cm) in treatment combination S_5F_2 **(**50% NPK + 50% Vermicompost + Bioinoculants + Wood ash) and minimum plant height increment (15.71 cm) in treatment combination S_8F_1 **(**100% FYM + Bioinoculants + Wood ash).

Data pertaining to the plant girth increment presented in Table-2 revealed that plant girth increment was significantly influenced with the conjoint application of soil and foliar nutrient sources during both the years of study. During 2021 highest plant girth increment (2.19 cm) was observed in treatment combination S_5F_2 **(**50% NPK + 50% Vermicompost + Bioinoculants + Wood ash) along with the foliar application of Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%) while lowest plant girth increment (0.99 cm) was observed in treatment combination S_8F_1 **(**100% FYM + Bioinoculants + Wood ash) Ca (0.2%) + B (0.1%) + Zn (0.4%) + K (1.4%). During 2022 maximum (2.22 cm) was observed in treatment combination S_5F_2, which was statistically at par with S_5F_0, whereas, minimum (1.07 cm) was observed in treatment combination S_8F_1. Similar trend was followed for the pooled data over both the years of study. Pooled data recorded maximum plant girth increment (2.22 cm) in treatment combination S_5F_2 and minimum plant girth increment (1.03 cm) in treatment combination S_8F_1.

Table 1: Impact of organic and inorganic nutrient sources on plant height increment (cm) of Apple (*Malus× domestica* Borkh) cv. Red Chief.

	2021				2022				Pooled			
Treatments	**F_0**	**F_1**	**F_2**	**Mean S**	**F_0**	**F_1**	**F_2**	**Mean S**	**F_0**	**F_1**	**F_2**	**Mean S**
S_0	23.33	23.23	23.47	23.34	24.60	24.48	24.77	24.62	23.97	23.86	24.12	23.98
S_1	21.33	21.20	21.47	21.33	22.52	22.37	22.68	22.52	21.93	21.79	22.08	21.93
S_2	25.27	25.07	25.70	25.34	26.92	26.70	27.39	27.00	26.10	25.89	26.55	26.18
S_3	26.50	26.30	26.97	26.59	28.28	28.05	28.80	28.38	27.39	27.18	27.89	27.49
S_4	24.40	24.13	24.60	24.38	25.93	25.63	26.17	25.91	25.17	24.88	25.39	25.15
S_5	32.50	32.23	33.03	32.59	34.56	34.26	35.12	34.65	33.53	33.25	34.08	33.62
S_6	28.87	28.27	28.97	28.70	30.82	30.19	30.94	30.65	29.85	29.23	29.96	29.68
S_7	17.43	17.20	17.50	17.38	18.51	18.25	18.59	18.45	17.97	17.73	18.05	17.92
S_8	15.33	15.20	15.90	15.48	16.35	16.21	16.93	16.50	15.84	15.71	16.42	15.99
S_9	19.37	19.20	19.63	19.40	20.50	20.31	20.77	20.53	19.94	19.76	20.20	19.97
Mean F	23.43	23.20	23.72		24.90	24.65	25.22		24.17	23.93	24.47	
Factors	C.D.											
Factor(F)	0.205				0.213				0.309			
Factor(S)	1.074				1.115				1.049			
Factor(F X S)	1.277				1.328				1.359			

Factor 1: Soil application

S_0 (Control): N% + P% + K% as recommended, S_1: 30% NPK + 70% FYM + Bioinnoculants + Wood ash, S_2: 50% NPK + 50% FYM + Bioinoculants + Wood ash, S_3: 70% NPK + 30% FYM + Bioinoculants + Wood ash, S_4: 30% NPK + 70% Vermicompost + Bioinoculants + Wood ash, S_5:50% NPK + 50% Vermicompost + Bioinoculants + Wood ash, S_6:70% NPK + 30% Vermicompost + Bioinoculants + Wood ash, S_7:50% FYM + 50% Vermicompost + Bioinoculants + Wood ash, S_8: 100% FYM + Bioinoculants + Wood ash, S_9: 100% Vermicompost + Bioinoculants + Wood ash.

Factor 2: Foliar application

F_0:Ca (0.3%) + B (0.15%) + Zn (0.5%) + K (1.5%), F_1:Ca (0.2%) + B (0.1%) + Zn (0.4%) + K (1.4%), F_2: Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%)

Table 2: Impact of organic and inorganic nutrient sources on plant girth increment (cm) of Apple (Malus × domestica Borkh) cv. Red Chief.

	2021				2022				Pooled			
Treatments	**F_0**	**F_1**	**F_2**	**Mean S**	**F_0**	**F_1**	**F_2**	**Mean S**	**F_0**	**F_1**	**F_2**	**Mean S**
S_0	1.26	1.24	1.27	1.26	1.31	1.58	1.34	1.41	1.29	1.41	1.31	1.33
S_1	1.15	1.14	1.21	1.17	1.25	1.24	1.26	1.25	1.21	1.19	1.23	1.21
S_2	1.49	1.46	1.76	1.57	1.57	1.53	1.82	1.64	1.51	1.52	1.79	1.61
S_3	1.89	1.74	1.97	1.87	1.95	1.81	1.99	1.92	1.92	1.78	1.98	1.89
S_4	1.39	1.36	1.46	1.40	1.48	1.44	1.52	1.48	1.44	1.40	1.49	1.44
S_5	2.14	2.11	2.19	2.14	2.19	2.15	2.25	2.20	2.17	2.13	2.22	2.17
S_6	2.13	2.05	2.18	2.12	2.18	2.09	2.22	2.16	2.16	2.07	2.21	2.15
S_7	1.10	1.07	1.17	1.11	1.18	1.13	1.29	1.20	1.14	1.10	1.23	1.16
S_8	1.06	0.99	1.07	1.04	1.01	1.07	1.16	1.08	1.04	1.03	1.12	1.06
S_9	1.11	1.09	1.12	1.11	1.18	1.21	1.23	1.21	1.15	1.15	1.18	1.16
Mean F	1.47	1.43	1.54		1.53	1.53	1.61		1.50	1.48	1.57	
Factors	C.D.											
Factor(F)	0.053				0.103				0.083			
Factor(S)	0.089				0.367				0.189			
Factor(F X S)	0.142				0.480				0.272			

Factor 1: Soil application

S_0 (Control): N% + P% + K% as recommended, S_1: 30% NPK + 70% FYM + Bioinnoculants + Wood ash, S_2: 50% NPK + 50% FYM + Bioinoculants + Wood ash, S_3: 70% NPK + 30% FYM + Bioinoculants + Wood ash, S_4: 30% NPK + 70% Vermicompost + Bioinoculants + Wood ash, S_5:50% NPK + 50% Vermicompost + Bioinoculants + Wood ash, S_6:70% NPK + 30% Vermicompost + Bioinoculants + Wood ash, S_7:50% FYM + 50% Vermicompost + Bioinoculants + Wood ash, S_8: 100% FYM + Bioinoculants + Wood ash, S_9: 100% Vermicompost + Bioinoculants + Wood ash.

Factor 2: Foliar application

F_0:Ca (0.3%) + B (0.15%) + Zn (0.5%) + K (1.5%), F_1:Ca (0.2%) + B (0.1%) + Zn (0.4%) + K (1.4%), F_2: Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%)

As evident from Table-3, significant differences were observed on plant spread increment when the plants were treated with combined application of soil and foliar nutrient sources during both the years of investigation. During 2021 maximum plant spread increment (34.20 cm) was observed in treatment combination (50% NPK + 50% Vermicompost + Bioinoculants + Wood ash) S_5F_2 along with the foliar application of Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%) while minimum plant height increment (23.97 cm) was observed in treatment combination (100% FYM + Bioinoculants + Wood ash) S_8F_1 along with the foliar application of Ca (0.2%) + B (0.1%) + Zn (0.4%) + K (1.4%). During 2022 highest (36.50 cm) was observed in treatment combination S_5F_2, which was statistically at par with S_5F_0, whereas, lowest (25.17 cm) was observed in treatment combination S_8F_1. Similar trend was followed for the pooled data over both the years. Pooled data recorded maximum plant spread increment (35.35 cm) in treatment combination S_5F_2 and minimum plant spread increment (24.57 cm) in treatment combination S_8F_1.

As evident from Table-4 indicated that significant differences were observed on plant spread increment when the plants were treated with combined application of soil and foliar nutrient sources during both the years of investigation. During 2021 maximum plant spread increment (34.20 cm) was observed in treatment combination **(**50% NPK + 50% Vermicompost + Bioinoculants + Wood ash) S_5F_2 along with the foliar application of Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%) while minimum plant height increment (23.97 cm) was observed in treatment combination **(**100% FYM + Bioinoculants + Wood ash) S_8F_1 along with the foliar application of Ca (0.2%) + B (0.1%) + Zn (0.4%) + K (1.4%). During 2022 highest (36.50 cm) was observed in treatment combination S_5F_2, which was statistically at par with S_5F_0, whereas, lowest (25.17 cm) was observed in treatment combination S_8F_1. Similar trend was followed for the pooled data over both the years. Pooled data recorded maximum plant spread increment (35.35 cm) in treatment combination S_5F_2 and minimum plant spread increment (24.57 cm) in treatment combination S_8F_1.

It is clear from the data presented in Table-5 indicated that interaction effect of soil and foliar applied nutrient sources significantly affected leaf area during both the years of study 2021 and 2022. During 2021 maximum leaf area (35.70 cm^2) was observed in treatment combination **(**50% NPK + 50% Vermicompost + Bioinoculants + Wood ash) S_5F_2 along with the foliar application of Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%) and minimum leaf area (20.70 cm^2) was observed in treatment combination **(**100% FYM + Bioinoculants + Wood ash) S_8F_1 along with the foliar application of Ca (0.2%) + B (0.1%) + Zn (0.4%) + K (1.4%). During 2022 highest (36.65 cm^2), was observed in treatment combination S_5F_2, which was statistically at par with S_5F_0, while lowest (20.99 cm^2) was observed in treatment combination S_8F_1. Similar pattern was followed for the pooled data over both the years. Pooled data showed maximum leaf area (36.18 cm^2) in treatment combination S_5F_2 and minimum leaf area (20.85 cm^2) in treatment combination S_8F_1.

Table 3: Impact of organic and inorganic nutrient sources on plant spread increment (cm) of Apple (*Malus* × *domestica* Borkh) cv. Red Chief.

	2021				2022				Pooled			
Treatments	**F_0**	**F_1**	**F_2**	**Mean S**	**F_0**	**F_1**	**F_2**	**Mean S**	**F_0**	**F_1**	**F_2**	**Mean S**
S_0	28.90	28.87	29.00	28.92	30.46	30.42	30.58	30.49	29.68	29.65	29.79	29.71
S_1	28.03	28.00	28.10	28.04	29.49	29.45	29.58	29.51	28.76	28.73	28.84	28.78
S_2	31.07	31.03	31.13	31.08	32.83	32.77	32.91	32.84	31.95	31.90	32.02	31.96
S_3	31.83	31.63	31.97	31.81	33.70	33.48	33.87	33.68	32.77	32.56	32.92	32.75
S_4	30.07	30.00	30.10	30.06	31.70	31.62	31.75	31.69	30.89	30.81	30.93	30.88
S_5	34.10	34.07	34.20	34.12	36.35	36.29	36.50	36.38	35.23	35.18	35.35	35.25
S_6	33.10	33.00	33.17	33.09	35.22	35.10	35.32	35.21	34.16	34.05	34.25	34.15
S_7	26.07	26.00	26.10	26.06	27.37	27.28	27.42	27.36	26.72	26.64	26.76	26.71
S_8	24.00	23.97	24.03	24.00	25.22	25.17	25.27	25.22	24.61	24.57	24.65	24.61
S_9	27.07	27.00	27.13	27.07	28.47	28.39	28.55	28.47	27.77	27.70	27.84	27.77
Mean F	29.42	29.36	29.49		31.08	31.00	31.18		30.25	30.18	30.34	
Factors	C.D.											
Factor(F)	0.083				0.094				0.077			
Factor(S)	0.846				0.639				0.851			
Factor(F X S)	0.929				0.733				0.928			

Factor 1: Soil application

S_0 (Control): N% + P% + K% as recommended, S_1: 30% NPK + 70% FYM + Bioinnoculants + Wood ash, S_2: 50% NPK + 50% FYM + Bioinoculants + Wood ash, S_3: 70% NPK + 30% FYM + Bioinoculants + Wood ash, S_4: 30% NPK + 70% Vermicompost + Bioinoculants + Wood ash, S_5:50% NPK + 50% Vermicompost + Bioinoculants + Wood ash, **S_6**:70% NPK + 30% Vermicompost + Bioinoculants + Wood ash, S_7:50% FYM + 50% Vermicompost + Bioinoculants + Wood ash, S_8: 100% FYM + Bioinoculants + Wood ash, S_9: 100% Vermicompost + Bioinoculants + Wood ash.

Factor 2: Foliar application

F_0:Ca (0.3%) + B (0.15%) + Zn (0.5%) + K (1.5%), F_1:Ca (0.2%) + B (0.1%) + Zn (0.4%) + K (1.4%), F_2: Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%)

Table 4: Impact of organic and inorganic nutrient sources on annual shoot growth extension (cm) of Apple (*Malus*× *domestica* Borkh) cv. Red Chief.

	2021				2022				Pooled			
Treatments	**F_0**	**F_1**	**F_2**	**Mean S**	**F_0**	**F_1**	**F_2**	**Mean S**	**F_0**	**F_1**	**F_2**	**Mean S**
S_0	20.22	19.89	20.70	20.27	21.34	20.99	21.85	21.39	20.78	20.44	21.28	20.83
S_1	19.31	18.97	19.64	19.31	20.36	20.00	20.71	20.36	19.84	19.49	20.17	19.83
S_2	22.46	21.98	22.72	22.38	23.78	23.28	24.06	23.70	23.12	22.63	23.39	23.04
S_3	23.46	22.99	23.72	23.39	24.88	24.38	25.17	24.81	24.17	23.69	24.45	24.10
S_4	21.26	20.97	21.68	21.30	22.48	22.17	22.93	22.53	21.87	21.57	22.31	21.92
S_5	25.42	25.03	26.02	25.49	27.16	26.73	27.81	27.23	26.29	25.88	26.91	26.36
S_6	24.51	23.99	24.83	24.44	26.06	25.49	26.42	25.99	25.29	24.74	25.63	25.22
S_7	17.05	16.16	17.42	16.88	17.86	16.95	18.25	17.69	17.46	16.56	17.84	17.29
S_8	15.38	14.71	15.83	15.31	16.10	15.41	16.59	16.03	15.74	15.06	16.21	15.67
S_9	18.29	17.85	18.61	18.25	19.26	18.80	19.60	19.22	18.78	18.33	19.11	18.74
Mean F	20.74	20.25	21.12		21.93	21.42	22.34		21.33	20.84	21.73	
Factors	C.D.											
Factor(F)	0.483				0.454				0.679			
Factor(S)	1.601				1.572				1.523			
Factor(F X S)	2.082				2.026				2.202			

Factor 1: Soil application

S_0 (Control): N% + P% + K% as recommended, S_1: 30% NPK + 70% FYM + Bioinnoculants + Wood ash, S_2: 50% NPK + 50% FYM + Bioinoculants + Wood ash, S_3: 70% NPK + 30% FYM + Bioinoculants + Wood ash, S_4: 30% NPK + 70% Vermicompost + Bioinoculants + Wood ash, S_5:50% NPK + 50% Vermicompost + Bioinoculants + Wood ash, S_6:70% NPK + 30% Vermicompost + Bioinoculants + Wood ash, S_7:50% FYM + 50% Vermicompost + Bioinoculants + Wood ash, S_8: 100% FYM + Bioinoculants + Wood ash, S_9: 100% Vermicompost + Bioinoculants + Wood ash.

Factor 2: Foliar application

F_0:Ca (0.3%) + B (0.15%) + Zn (0.5%) + K (1.5%), F_1:Ca (0.2%) + B (0.1%) + Zn (0.4%) + K (1.4%), F_2: Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%)

Table 5: Impact of organic and inorganic nutrient sources on leaf area (cm^2) of Apple (*Malus* × *domestica* Borkh) cv. Red Chief.

	2021				2022				Pooled			
Treatments	**F_0**	**F_1**	**F_2**	**Mean S**	**F_0**	**F_1**	**F_2**	**Mean S**	**F_0**	**F_1**	**F_2**	**Mean S**
S_0	30.40	30.30	30.50	30.40	30.96	30.85	31.08	30.96	30.68	30.58	30.79	30.68
S_1	28.87	28.77	29.30	28.98	29.36	29.25	29.81	29.47	29.12	29.01	29.56	29.23
S_2	33.67	33.57	33.83	33.69	34.33	34.22	34.51	34.35	34.00	33.90	34.17	34.02
S_3	34.53	34.27	34.60	34.47	35.25	34.98	35.35	35.19	34.89	34.63	34.98	34.83
S_4	31.70	31.67	31.80	31.72	32.31	32.27	32.43	32.34	32.01	31.97	32.12	32.03
S_5	35.67	35.60	35.70	35.66	36.58	36.49	36.65	36.57	36.13	36.05	36.18	36.12
S_6	34.77	34.70	35.01	34.82	35.56	35.48	35.82	35.62	35.17	35.09	35.41	35.22
S_7	24.47	24.40	24.97	24.61	24.82	24.74	25.34	24.96	24.65	24.57	25.16	24.79
S_8	20.77	20.70	20.97	20.81	21.07	20.99	21.29	21.11	20.92	20.85	21.13	20.96
S_9	27.23	26.93	27.60	27.26	27.64	27.33	28.03	27.67	27.44	27.13	27.82	27.47
Mean F	30.21	30.09	30.43		30.79	30.66	31.03		30.50	30.38	30.73	
Factors	C.D.											
Factor(F)	0.105				0.109				0.115			
Factor(S)	0.486				0.691				0.551			
Factor(F X S)	0.591				0.800				0.666			

Factor 1: Soil application

S_0 (Control): N% + P% + K% as recommended, S_1: 30% NPK + 70% FYM + Bioinnoculants + Wood ash, S_2: 50% NPK + 50% FYM + Bioinoculants + Wood ash, S_3: 70% NPK + 30% FYM + Bioinoculants + Wood ash, S_4: 30% NPK + 70% Vermicompost + Bioinoculants + Wood ash, S_5:50% NPK + 50% Vermicompost + Bioinoculants + Wood ash, S_6:70% NPK + 30% Vermicompost + Bioinoculants + Wood ash, S_7:50% FYM + 50% Vermicompost + Bioinoculants + Wood ash, S_8: 100% FYM + Bioinoculants + Wood ash, S_9: 100% Vermicompost + Bioinoculants + Wood ash.

Factor 2: Foliar application

F_0:Ca (0.3%) + B (0.15%) + Zn (0.5%) + K (1.5%), F_1:Ca (0.2%) + B (0.1%) + Zn (0.4%) + K (1.4%), F_2: Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%)

The maximum vegetative growth in terms of plant height, spread, annual extension in growth and leaf area might be due to the improved photosynthetic rate and carbohydrate accumulation as a result of multiferous role of vermicompost to permit most favorable conditions of soil with increased accessibility of plant nutrients responsible for better plant growth [Sharma and Bhutani (2000); Dutta *et al*. (2009); Goswami *et al.* (2012) and Pathak and Ram (2005)] [20, 8, 11, 17]. The increasing activity of microflora in the rhizosphere also promotes increased nutrient availability and hence, vigorous plant growth (Singh *et al*., 2000; Aseri *et al.*, 2008) [22, 4]. The biofertilizers innoculation helps the plants to increase the dehydrogenase, alkaline phosphatase, nitrogenase and hydrolysis enzyme activities mainly due to increase in the rhizosphere microbial population as a consequence of the inoculation treatments (Aseri and Tarafdar, 2006) [3]. The adequate supply of multinutrients, resulted in their proper utilization in the process of photosynthesis due to increase in the leaf number and leaf size i.e. photosynthetic area. Thus, the increased production of photosynthates (food material) brought about increase in the vegetative growth parameters. Leaf is the principal site of plant metabolism and the changes in nutrients supply are reflected in the composition of leaf Dwivedi and Agnihotri (2018) [9]. Similar results have been confirmed by Athani *et al.*, (2007) [5], Naik and Babu (2007) [15], Ram *et al.*, (2007) [19], Kumar *et al.*, (2007) [14], Dutta *et al.*, (2009) [8], Patel *et al.* (2009) [16], Shukla *et al.* (2009) [21], Dwivedi (2013) [10] and Agnihotri *et al.* (2013) [1].

Conclusion

From the present investigation it was concluded that the integrated use of 70% NPK + 30% (Vermicompost + Bionoculants + Wood ash) along with the foliar application of Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%) is recommended for growers seeking improved growth characteristics of the plant. 50% NPK + 50% (Vermicompost + Bionoculants + Wood ash) along with the foliar application of Ca (0.5%) + B (0.2%) + Zn (0.6%) + K (1.6%) can be employed to enhance plant growth attributes. These findings contribute to the knowledge base of sustainable horticultural practices and serve as a valuable resource for apple growers and researchers, aiding in the development of targeted nutrient management strategies that maximize yield potential and ensure the production of high-quality apples.

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