Effects of Organic and Inorganic Fertilizers on Soil Properties, Nutrient Dynamics, and Maize Yield (*Zea mays* L.)

Abstract

A field experiment was carried out during the *summer* seasons of 2021-22 and 2022-23 at the Zonal Agriculture Research Station at Chhindwara. The objective of the experiment was to investigate the impact of various organic and inorganic fertilizers on the nutrient content (N, P, K & Zn), uptake and yield of maize. The experiment was structured using a randomized block design, incorporating ten treatments and three replications. The treatments were, T_1 - Control (0:0:0), T_2 - 100% RDF (120:60:40 kg NPK ha^{-1}), T_3 - 75% RDF, T_4 - 50 % RDF, T_5 - FYM 10 t ha^{-1} + Azotobacter, T_6 - 100 % RDF + 5 t ha^{-1} FYM, T_7 - 75 % RDF + 5 t ha^{-1} FYM, T_8 - 50 % RDF + 5 t ha^{-1} FYM, T_9 - 100 % RDF + 5 kg Zn ha^{-1} and T_{10} - FYM 5 t ha^{-1} (State practice). The result revealed that the application of 100 % RDF + 5 t ha^{-1} FYM (T_6) recorded higher values of soil chemical properties *viz*., pH (7.167), EC (0.329), OC (0.350), available nitrogen (340.50), phosphorus (15.92) and potassium (320.26), nitrogen content in grain (1.638) and stover (0.482), phosphorus content in grain (0.407) and stover (0.040), potassium content in grain (0.554) and stover (1.636), nitrogen uptake (196.347), phosphorus uptake (36.107), potassium uptake (275.869), Zn content in grain (30.460 ppm) and stover (21.242 ppm), grain yield (7957.53 kg ha^{-1}) and stover yield (14473.65 kg ha^{-1}).

1. Introduction

The latter part of the 20th century has witnessed sustained increases in global maize output, establishing maize (*Zea mays* L.) as the predominant crop worldwide in terms of production during the past decade. Maize has a significant chance to augment the national food supply because of high yield potential and flexibility. In India, maize is the third most significant cereal crop after rice and wheat as well in the world (Amanullah *et al*., 2007 and Dilshad *et al*., 2010). Maize supplies food, feed, fodder and acts as a source of fundamental raw material for the number of industrial goods *viz*., starch, protein, oil, alcoholic drinks, food sweeteners, cosmetics, more recently as bio-fuel, *etc*. No other cereal is being used in as many ways as maize. Maize grain has enhanced nutritious value as it comprises around 72% starch, 10% protein, 4.8% oil, 5.8% fiber and 3% sugar (Rafiq *et al*., 2010). In India, the maize is utilised as human food (23%), poultry feed (51%), animal feed (12%), industrial (starch) goods (12%), beverages and seed (1%). It comprises 9.48 percent of total cereal output (rice, wheat, maize, bajra and jowar). In India, it spans an area of 9.86 m ha with output of 32.42 million tonnes and productivity status of 3288.03 kg ha^{-1} providing about 10.46 per cent in the national food basket (Department of Agriculture and Farmers Welfare, 2nd Advance projection 2021-22). In Madhya Pradesh, it is cultivated in an area of 1537.09 thousand ha with an average production of 4489.58 thousand tonnes and productivity of 2.92 tonnes/ha (Madhya Pradesh Economic Survey, 2020-21). It is mostly farmed as *kharif* crop in Chhindwara, Seoni, Betul, Barwani and Dhar districts of Madhya Pradesh. Maize is an exhausting crop demands all sorts of macro and micro nutrients for optimal development and production potential. Therefore, it needs fertile soil to express its production potential. The organic and inorganic refers "a system which aim to improve and maintain soil fertility for sustaining crop productivity and involves the use of chemical fertilizers in conjunction with organic manures which are rich input through biological process". In combination of organic sources, *i.e*. farmyard manure (FYM) and bio-fertilizers such as Azotobactor together with chemical fertilizers, efficient in boosting the nutrient availability in soil, improving physical qualities of soil and its organic carbon status. In this quest adequate mix of organic and inorganic fertilizer is vital not only for improving output but also for keeping soil health. Boosting output, decreasing production cost and enhancing soil health are three inter-linked components of the sustainable triangle. The combined use of chemical and organic fertilizer on production and yield components of maize is highly critical for assurance of food security (Sindhi *et al*., 2018 and Singh *et al*., 2018). For sustainable crop production and sustaining soil quality, input of organic manure is of vital importance and should be recommended in the nutrient management of intensive cropping system for enhancing soil fertility and biological characteristics of soils (Khan and Wani, 2017).

Material and Methods

A study titled "Impact of Different Organic and Inorganic Fertilizers On chemical properties, nutrient content, uptake and yield of Maize (*Zea mays* L.)" was conducted during the *winter* season of 2021-22 and 2022-23 at the Zonal Agriculture Research Station, Chhindwara. To evaluate the impact of various organic and inorganic fertilizers on the yield performance of maize with nutrients content and their uptake. The experiment was designed using a randomized block layout, consisting of ten treatments and three replications. The treatments were, T_1 - Control (0:0:0), T_2 - 100% RDF (120:60:40 kg NPK ha^{-1}), T_3 - 75% RDF, T_4 - 50 % RDF, T_5 - FYM 10 t ha^{-1} + Azotobacter, T_6 - 100 % RDF + 5 t ha^{-1} FYM, T_7 - 75 % RDF + 5 t ha^{-1} FYM, T_8 - 50 % RDF + 5 t ha^{-1} FYM, T_9 - 100 % RDF + 5 kg Zn ha^{-1}, T_{10} - FYM 5 t ha^{-1} (State practice). In addition to grain and straw yield, chemical properties were also recorded. The key results of the study have been documented and analysed in the following sections.

Result and Discussions

The nutrient composition of maize grains and stover, including nitrogen (N), phosphorus (P), potassium (K), and zinc (Zn), varied significantly across treatments. For nitrogen content in grain, the highest percentage (1.638%) was recorded in T_6 (100% RDF + 5 t/ha FYM), which was statistically at par with T_9 (100% RDF + 5 kg Zn/ha, 1.628%) and T_7 (75% RDF + 5 t/ha FYM, 1.552%). The lowest nitrogen content (1.243%) was observed in T_1 (Control). Regarding phosphorus content in grain, T_6 (100% RDF + 5 t/ha FYM) achieved the highest value (0.407%), statistically at par with T_9 (100% RDF + 5 kg Zn/ha, 0.383%) and T_7 (75% RDF + 5 t/ha FYM, 0.356%), while T_1 (Control) recorded the lowest phosphorus content (0.215%). For potassium content in grain, the maximum value (0.554%) was noted in T_6 (100% RDF + 5 t/ha FYM), statistically at par with T_9 (100% RDF + 5 kg Zn/ha, 0.532%) and T_7 (75% RDF + 5 t/ha FYM, 0.482%), whereas T_1 (Control) had the lowest potassium content (0.325%). In terms of Zinc content in grain, the highest value (30.46 ppm) was observed in T_6 (100% RDF + 5 t/ha FYM), which was statistically at par with T_9 (100% RDF + 5 kg Zn/ha, 27.51 ppm) and T_7 (75% RDF + 5 t/ha FYM, 26.36 ppm). The lowest zinc content in grain (18.023 ppm) was recorded in T_1 (Control). Similarly, for zinc content in stover, T_6 (100% RDF + 5 t/ha FYM) again showed the highest concentration (21.242 ppm), which was statistically at par with T_9 (100% RDF + 5 kg Zn/ha, 20.938 ppm) and T_7 (75% RDF + 5 t/ha FYM, 19.185 ppm). The lowest zinc content in stover (10.23 ppm) was observed in T_1 (Control). Overall, T_6 (100% RDF + 5 t/ha FYM) consistently demonstrated the highest values across all parameters, highlighting the synergistic effect of combining inorganic and organic fertilizers. The control treatment (T_1) consistently recorded the lowest nutrient levels in both grain and stover, emphasizing the importance of balanced and integrated nutrient management for enhancing maize quality and nutrient uptake. Similar results were reported by Similar result reported by Bisht *et al.* (2013), Ravi *et al.* (2013), Mahmood *et al.* (2017), Dharaiya *et al.* (2018) and Prajapati *et al.* (2022).

The nutrient uptake (N, P, and K) by maize plants varied significantly across treatments. For nitrogen (N) uptake, the highest value (196.347 kg/ha) was recorded in T_6 (100% RDF + 5 t/ha FYM), which was statistically at par with T_9 (100% RDF + 5 kg Zn/ha, 186.290) and T_7 (75% RDF + 5 t/ha FYM, 166.387). The lowest N uptake (103.154 kg/ha) was observed in T_1 (Control). In terms of phosphorus (P) uptake, the maximum value (36.107 kg/ha) was observed in T_6 (100% RDF + 5 t/ha FYM), which was statistically at par with T_9 (100% RDF + 5 kg Zn/ha, 36.038 kg/ha) and T_7 (75 % RDF + 5 t/ha FYM, 29.902 kg/ha). The lowest phosphorus uptake (14.345 kg/ha) was recorded in T_1 (Control). Similarly, for potassium (K) uptake, the highest uptake (275.869 kg/ha) was observed in T_6 (100% RDF + 5 t/ha FYM), which was statistically at par with

T_9 (100% RDF + 5 kg Zn/ha, 252.580 kg/ha) and T_7 (75 % RDF + 5 t/ha FYM, 29.902 kg/ha). The lowest potassium uptake (144.268 kg/ha) was recorded in T_1 (Control). Among the treatments, T_9 (100% RDF + 5 kg Zn/ha) and T_6 (100% RDF + 5 t/ha FYM) consistently recorded the highest uptake values for all nutrients, highlighting their effectiveness in enhancing nutrient use efficiency. On the other hand, the control (T_1) showed the lowest uptake values for N, P, and K, demonstrating the necessity of nutrient supplementation to achieve optimal nutrient uptake and crop performance. Similar result reported by Similar result reported by Guang-hao *et al.* (2021) and Zingore *et al.* (2022).

The soil parameters, including pH, EC (electrical conductivity), and OC (organic carbon), were influenced by different nutrient treatments, but the differences were statistically non-significant at the 5% level of significance (CD, P = 0.05). Despite this, some notable trends were observed. The highest pH value (7.177) was recorded in T_9 (100% RDF + 5 kg Zn/ha), followed by T_6 (100% RDF + 5 t/ha FYM, 7.167), while the lowest pH (6.982) was observed in T_1 (Control). For EC, the highest value (0.329 dS/m) was recorded in T_9 (100% RDF + 5 kg Zn/ha) and T_6 (100% RDF + 5 t/ha FYM), whereas the lowest (0.320 dS/m) was noted in T_1 (Control). Regarding organic carbon, the highest value (0.382) was observed in T_3 (75% RDF) and T_8 (50% RDF + 5 t/ha FYM), while the lowest value (0.346) was recorded in T_1 (Control). Although the results were not statistically significant, the data suggest that integrated nutrient management practices, especially those involving FYM and a combination of organic and inorganic fertilizers (T_6: 100% RDF + 5 t/ha FYM, T_9: 100% RDF + 5 kg Zn/ha, and T_7: 75% RDF + 5 t/ha FYM), tend to improve soil health parameters such as pH, EC, and OC compared to the control. These trends highlight the potential of nutrient supplementation to enhance soil quality over time. Similar result reported by Sathish *et al.* (2011), Hargilas (2012), Ahmad *et al.* (2013), Bisht *et al.* (2013), Ravi *et al.* (2013), Mahmood *et al.* (2017) and Prajapati *et al.* (2022).

The nutrient content of maize plants, including nitrogen (N), phosphorus (P), and potassium (K), was significantly influenced by different treatments. For Nitrogen content, the highest value (340.5 kg/ha) was observed in T_6 (100% RDF + 5 t/ha FYM), which was statistically at par with T_9 (100% RDF + 5 kg Zn/ha, 333.5 kg/ha) and T_7 (75% RDF + 5 t/ha FYM, 320 kg/ha). The lowest nitrogen content (252.5 kg/ha) was recorded in T_1 (Control). Similarly, for phosphorus content, the highest value (15.917 kg/ha) was recorded in T_6 (100% RDF + 5 t/ha FYM), which was statistically at par with (100% RDF + 5 kg Zn/ha, 15.134 kg/ha) and T_7 (75% RDF + 5 t/ha FYM, 13.435 kg/ha). The lowest phosphorus content (6.111 kg/ha) was again observed in T_1 (Control). In terms of potassium content, the maximum value (320.262 kg/ha) was obtained in T_6 (100% RDF + 5 t/ha FYM), which was statistically at par with T_9 (100% RDF + 5 kg Zn/ha, 315.203 kg/ha) and T_7 (75% RDF + 5 t/ha FYM, 299.815 kg/ha). The lowest potassium content (225.802 kg/ha) was recorded in T_1 (Control). Overall, T_6 (100% RDF + 5 t/ha FYM) consistently exhibited the highest nutrient content across nitrogen (N), phosphorus (P), and potassium (K), followed closely by T_9 (100% RDF + 5 kg Zn/ha) and T_7 (75% RDF + 5 t/ha FYM), which were statistically similar for all three parameters. The control treatment (T_1) consistently showed the lowest values, emphasizing the importance of balanced and integrated nutrient management for enhancing nutrient uptake and overall crop productivity. Similar result reported by Similar result reported by Bisht *et al*. (2013), Ravi *et al*. (2013), Mahmood *et al*. (2017) and Prajapati *et al*. (2022).

The grain and stover yields of soybean varied significantly across treatments. The highest grain yield (7947.53 kg/ha) was recorded in T_6 (100% RDF + 5 t/ha FYM), which was statistically at par with T_9 (100% RDF + 5 kg Zn/ha, 7583.03 kg/ha) and T_7 (75% RDF + 5 t/ha FYM, 7008.39 kg/ha), while the lowest grain yield (5373.98 kg/ha) was observed in the control treatment (T_1). Similarly, for stover yield, the highest value (14,473.65 kg/ha) was obtained in T_6 (100% RDF + 5 t/ha FYM), which was statistically at par with T_9 (100% RDF + 5 kg Zn/ha, 12,880.52 kg/ha) and T7 (75% RDF + 5 t/ha FYM, 12,728.96 kg/ha). The lowest stover yield (9997.98 kg/ha) was recorded in T_1 (Control). These results indicate that T_6 (100% RDF + 5 t/ha FYM) consistently achieved the highest grain and stover yields, followed by T_9 (100% RDF + 5 kg Zn/ha) and T_7 (75% RDF + 5 t/ha FYM), which were statistically comparable. On the other hand, the control treatment (T1) consistently recorded the lowest yields, highlighting the critical role of integrated nutrient management practices in improving soybean productivity. Bisht *et al*. (2013), Ravi *et al*. (2013), Mahmood *et al*. (2017), Barde *et al*. (2021) and Prajapati *et al*. (2022).

Conclusion

The study demonstrated that integrated nutrient management practices significantly enhanced soil health, nutrient content, and nutrient uptake in maize compared to the control. The treatment T_6 (100% RDF + 5 t/ha FYM) consistently recorded the highest values for nutrient content (N, P, and K) in grain and stover, nutrient uptake (N, P, and K), and soil parameters (pH, EC, and OC), closely followed by T_9 (100% RDF + 5 kg Zn/ha) and T_7 (75% RDF + 5 t/ha FYM). These treatments were statistically at par for most parameters, indicating their effectiveness in enhancing crop productivity and nutrient use efficiency. The control treatment (T_1) consistently recorded the lowest values, emphasizing the critical need for balanced and integrated nutrient management. This study highlights the potential of combining organic and inorganic fertilizers, particularly FYM and zinc supplementation, to improve soil fertility, crop nutrition, and sustainable maize productivity.

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Table 1: Effect of organic and inorganic fertilizers on nutrient content and their uptake by maize crop (Pooled data of 2021-22 and 2022-23)

Treatments	Nutrient content (%)								Nutrient uptake (kg ha^{-1})			Yield (kg ha^{-1})	
	N (%)		P (%)		K (%)		Zn		N	P	K	Grain Yield	Stover Yield
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover					
Control (0:0:0) (T_1)	1.243	0.364	0.215	0.028	0.325	1.268	18.023	10.230	103.154	14.345	144.268	5373.98	9997.98
100% RDF (T_2)	1.569	0.445	0.347	0.037	0.463	1.571	25.789	17.753	173.262	30.397	238.062	7362.23	12979.08
75% RDF (T_3)	1.476	0.437	0.305	0.034	0.435	1.510	25.003	16.964	146.974	23.724	207.923	6425.04	11913.14
50 % RDF (T_4)	1.385	0.417	0.280	0.033	0.402	1.394	23.585	14.791	133.398	21.059	185.922	6144.21	11566.92
FYM 10 t/ha + Azotobacter (T_5)	1.330	0.403	0.267	0.032	0.383	1.353	22.817	13.448	124.835	19.504	175.787	5963.39	11292.10
100 % RDF + 5 t/ha FYM (T_6)	1.638	0.482	0.407	0.040	0.554	1.636	30.460	21.242	196.347	36.107	275.869	7583.03	12880.52
75 % RDF + 5 t/ha FYM (T_7)	1.552	0.451	0.356	0.038	0.482	1.578	26.360	19.185	166.387	29.702	234.920	7008.39	12728.96
50 % RDF + 5 t/ha FYM (T_8)	1.432	0.427	0.292	0.035	0.417	1.448	24.416	15.410	152.955	24.709	211.269	6931.83	12584.19
100 % RDF + 5 kg Zn/ha (T_9)	1.628	0.461	0.383	0.038	0.532	1.612	27.510	20.938	186.290	36.038	252.580	7947.53	14473.65
FYM 5 t/ha (State practice) (T_{10})	1.287	0.380	0.255	0.030	0.363	1.301	20.67	12.095	111.354	17.414	155.216	5600.88	10372.76
SE (m)	**0.043**	**0.019**	**0.018**	**0.002**	**0.021**	**0.043**	**1.315**	**0.796**	**14.782**	**3.355**	**21.563**	**765.86**	**1244.13**
CD P= 0.05	**0.123**	**0.055**	**0.050**	**0.005**	**0.062**	**0.122**	**3.773**	**2.282**	**42.397**	**9.624**	**61.845**	**2196.61**	**3568.36**

Table 2: Effect of organic and inorganic fertilizers on physio-chemical soil properties (Pooled data of 2021-22 and 2022-23)

Treatments	pH	EC (dS/m)	OC (%)	Available nutrient (kg ha^{-1})		
				N	P	K
Control (0:0:0) (T_1)	6.982	0.320	0.346	252.500	6.111	225.802
100% RDF (T_2)	7.121	0.326	0.380	314.833	12.425	291.752
75% RDF (T_3)	7.107	0.325	0.382	305.667	10.846	266.150
50 % RDF (T_4)	7.075	0.323	0.369	280.498	9.205	255.520
FYM 10 t/ha + Azotobacter (T_5)	7.035	0.322	0.366	273.498	7.998	239.713
100 % RDF + 5 t/ha FYM (T_6)	7.167	0.329	0.350	340.500	15.917	320.262
75 % RDF + 5 t/ha FYM (T_7)	7.132	0.327	0.373	320.000	13.435	299.815
50 % RDF + 5 t/ha FYM (T_8)	7.085	0.323	0.380	295.668	10.212	260.027
100 % RDF + 5 kg Zn/ha (T_9)	7.177	0.329	0.358	333.500	15.134	315.203
FYM 5 t/ha (State practice) (T_{10})	7.008	0.321	0.350	268.667	7.054	232.785
SE (m)	**0.175**	**0.014**	**0.020**	**9.092**	**0.886**	**9.244**
CD P= 0.05	**NS**	**NS**	**NS**	**26.079**	**2.542**	**26.513**

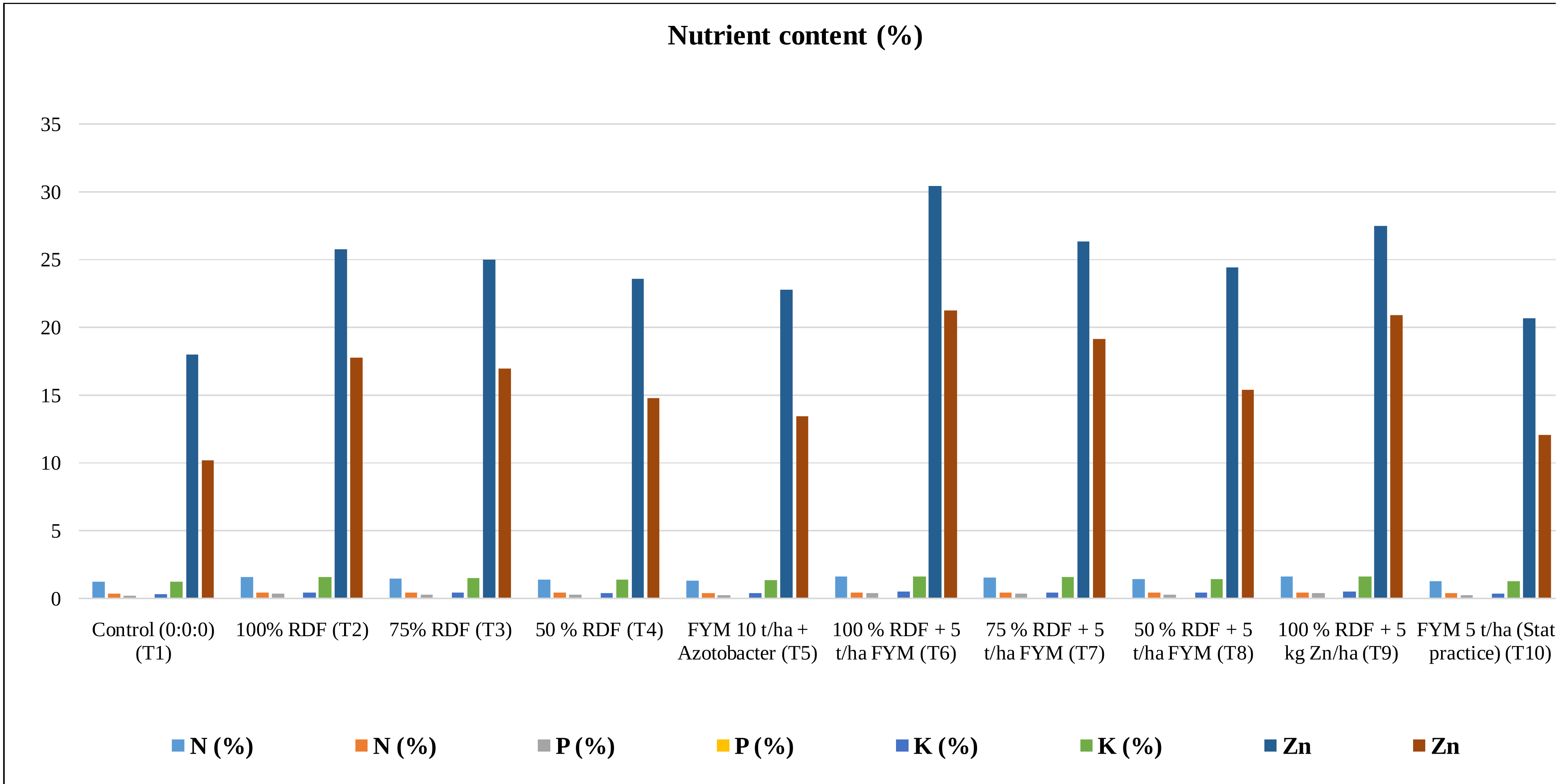

Figure 1: Effect of organic and inorganic fertilizers on nutrient content by maize crop (Pooled data of 2021-22 and 2022-23)

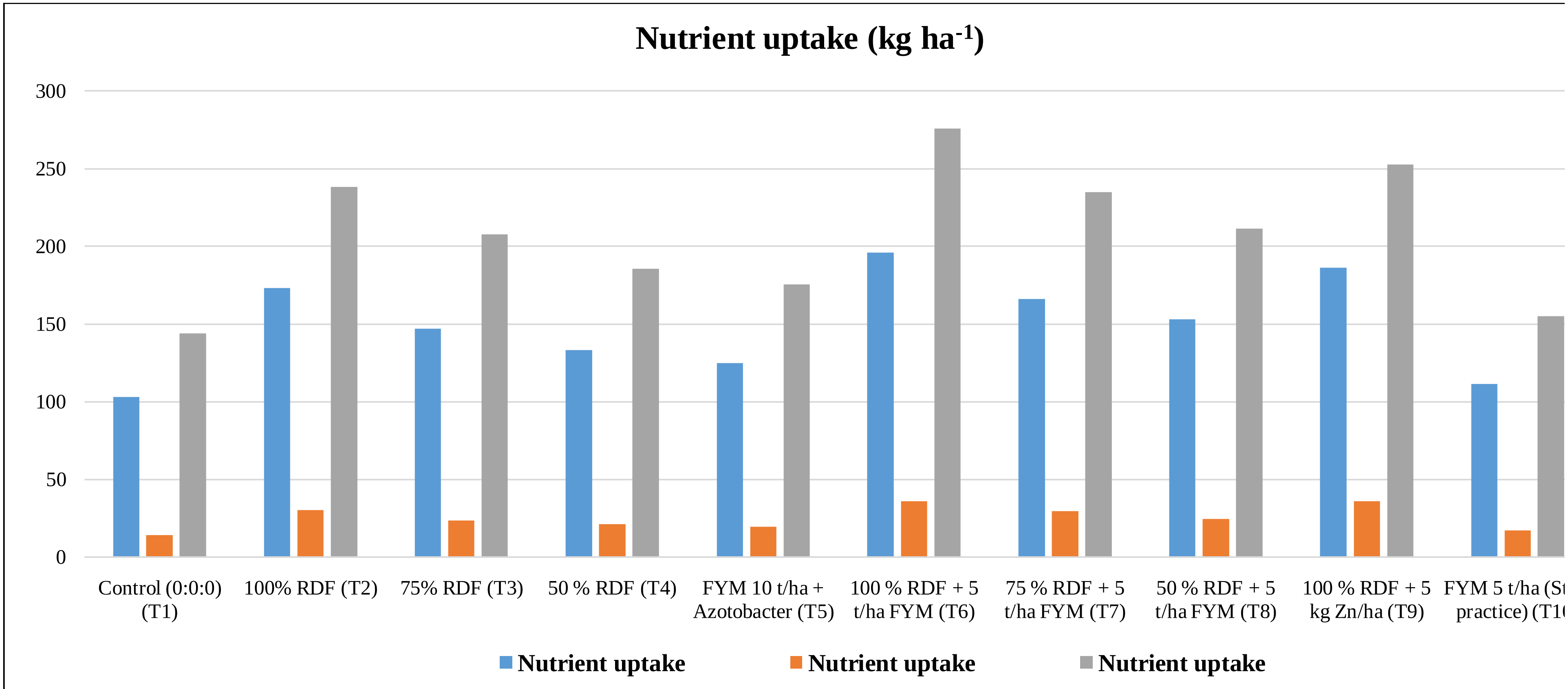

Figure 2: Effect of organic and inorganic fertilizers on nutrient uptake by maize crop (Pooled data of 2021-22 and 2022-23)

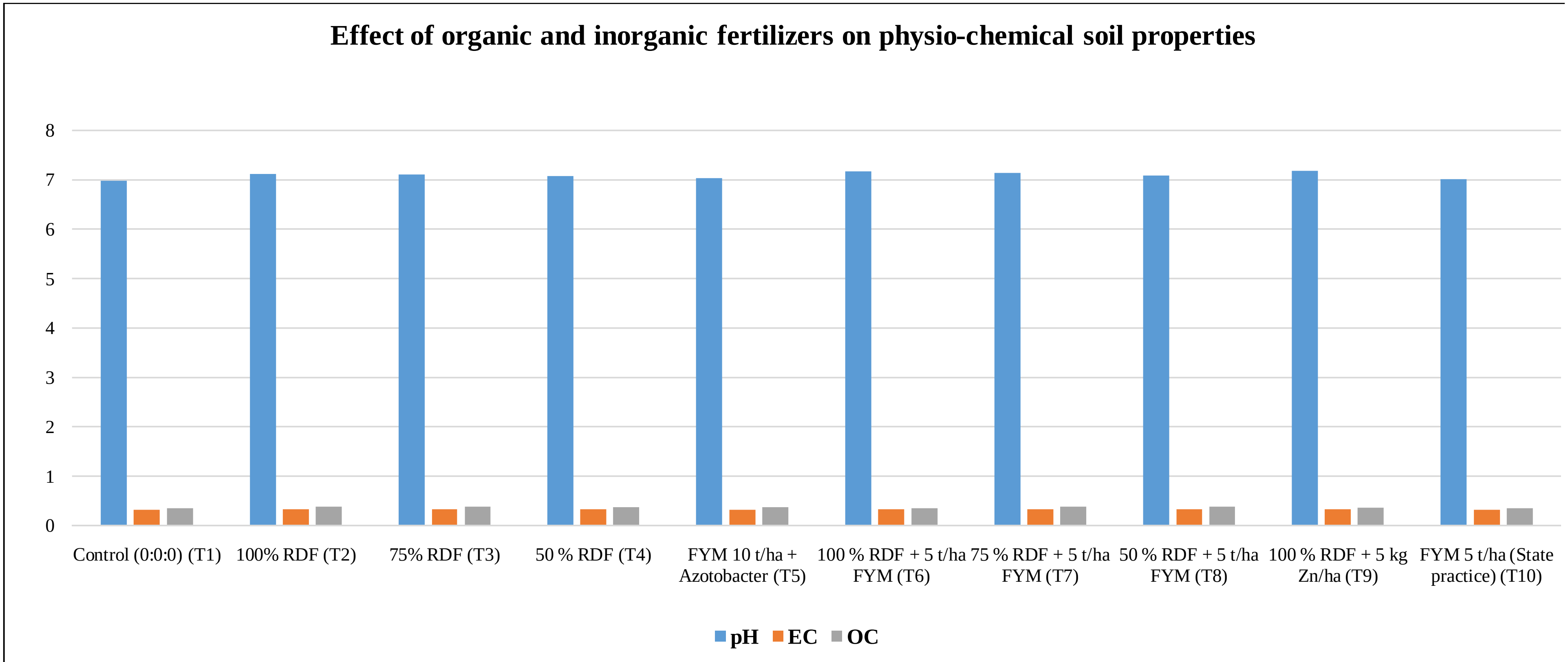

Figure 3: Effect of organic and inorganic fertilizers on physio-chemical parameters (Pooled data of 2021-22 and 2022-23)

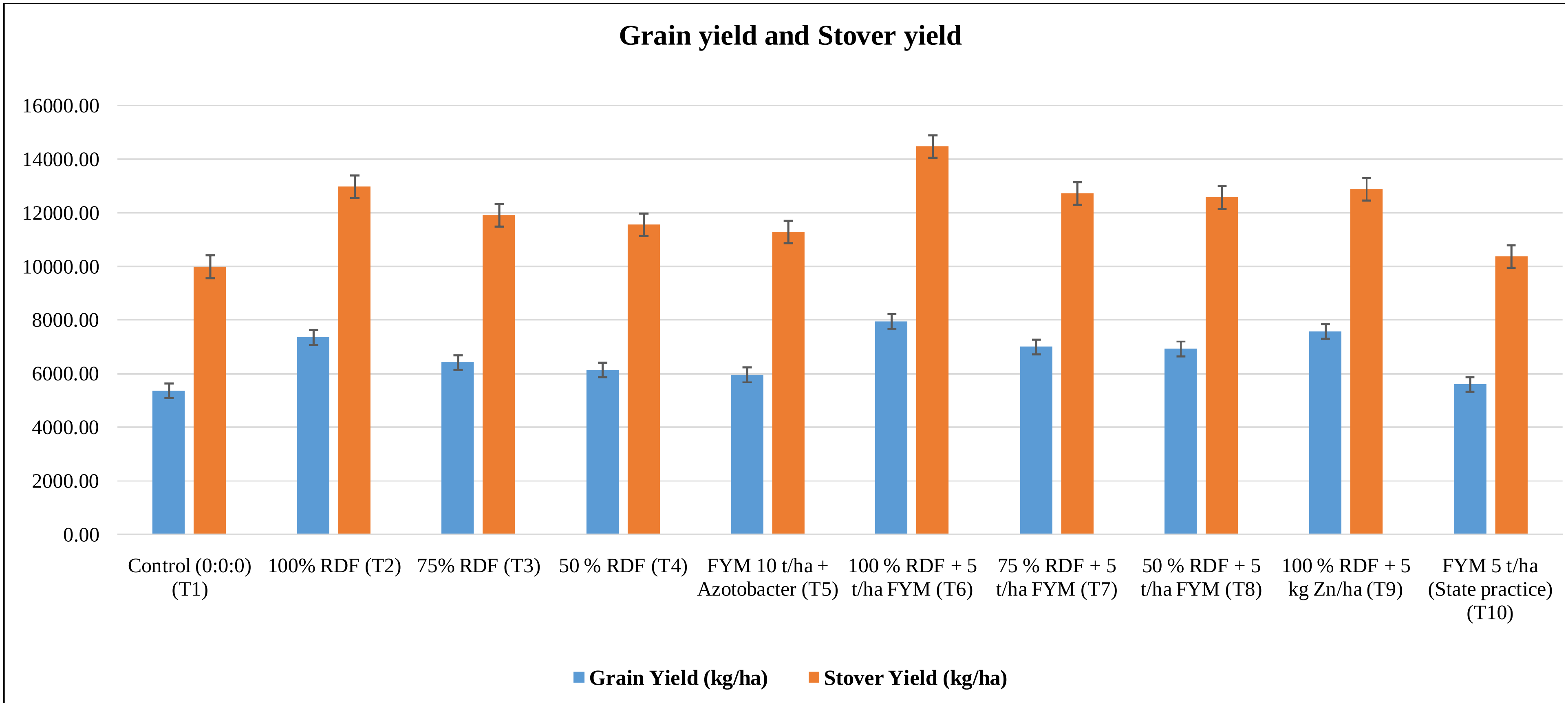

Figure 4: Effect of organic and inorganic fertilizers on grain and stover yield of maize (Pooled data of 2021-22 and 2022-23)