



Effect of Integrated Use of Organic Manures and Chemical Fertilizers under Soil Test Crop Response Approach on Soil Properties and Yield of Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration between both authors. Authors VP and AS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author VP managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, during *kharif* 2019 to study the effect of integrated use of organic manures and chemical fertilizers under STCR approach on physico-chemical, biological properties of soil and yield of maize crop in a Mollisol. The experiment comprised of 9 treatments replicated thrice. The treatment details were Control (no fertilizers), RDF, STCR (inorganic mode), STCR INM mode, 75% STCR dose of N (inorganic mode) + Green manure, 50% STCR dose of N (inorganic mode) + Green Manure, 75% RDN + Green Manure, 50% RDN + Green Manure and FYM + Green Manure + Intercropping with urd. The lowest yield and soil properties were observed under control. The highest water holding capacity (63.20%), available N (183.98 kg ha⁻¹), available P (28.94 kg ha⁻¹), microbial biomass carbon (335.35 µg/g soil) and urease enzyme activity (30.06 µg urea/g soil/h) was observed under T4 (STCR INM mode). The highest organic carbon (0.99%), available K (200.85 kg ha⁻¹) and dehydrogenase activity (223.60 µgTPF/gsoil/day) was observed under T5

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(75% STCR dose of N (inorganic mode) + Green manure). The highest maize yield was observed under T4 (STCR INM mode). Therefore, the present investigation clearly reveals the significance of balanced and efficient utilization of resources under STCR approach on soil and crop productivity of maize crop.

Keywords: Integrated; organic manures; chemical fertilizers; soil test crop response; soil properties; yield.

1. INTRODUCTION

Chemical fertilizers play an important role in increasing crop yields in order to feed the ever increasing population. But, blanket application of fertilizers without any information about the soil fertility status has affected the crop and soil adversely. Presently, fertilizer application is based on the nutrient requirement of an individual crop without any consideration of the soil test value or residual effect of the added sources to the previous crop. Increasing cost of the fertilizers has necessitated that every unit of fertilizer must be used judiciously. Organic manure plays a vital role in supplementing the nutrient requirement of crop and for sustaining soil fertility, crop productivity, reducing fertilizer doses and restoring overall soil quality. Therefore, in order to increase the agriculture production, judicious use of organic manures and chemical fertilizer as well as knowledge about the fertility status of soil is important [1].

Soil Test Crop Response (STCR) based nutrient application is one of the most efficient approach that ensures balanced and economic fertilizer use. STCR approach aims at adjustment of fertilizer doses under varying soil test values and for achieving the target yield of crop in a specific agro-climatic region by using mathematical equations [2]. These equations are then tested in follow up verification trials. This approach also takes into consideration percentage contribution from soil, percentage contribution from added fertilizer or organic manures and nutrient requirement for a desired target level. The impact of excessive use of fertilizers on soil quality, crop productivity and environmental quality has necessitated use of site-specific nutrient management (SSNM), integrated nutrient management (INM) taking into account the crop requirements, soil test values and yield target level. Therefore, the present study has been undertaken to study the soil and applied nutrient behavior for balanced fertilization and to validate the fertilizer prescription equations which were developed for maize crop in a Mollisol.

2. MATERIALS AND METHODS

2.1 Experimental Site and Climate of Area

A field experiment was conducted during *kharif* 2019 at Norman. E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, U. S. Nagar, Uttarakhand. The experimental field lies in *tarai* belt of Uttarakhand in the foot hills of *shivalik* range of Himalayas located at 29° N latitude 79° 30' E longitude and at an altitude of 243.8 m above the mean sea level and falls in humid sub tropical crop climatic zone. Taxonomically, the soil of the study area falls in the order 'Mollisol' and sub group 'Udoll'. Soil was sandy clay loam in texture and near to neutral in reaction.

2.2 Experimental Design and Treatment Details

The soil test based fertilizer prescription equations developed for targeted yield of maize under STCR and STCR-INM (Soil Test Crop Response-Integrated Nutrient Management) approach were used for application of nutrients from chemical fertilizers and farmyard manure (FYM) [3] (Table 1). The experiment was laid out in randomized block design (RBD) with nine treatments and three replications (Table 2). Based on the fertilizer adjustment equations, nutrients doses (kg ha^{-1}) from fertilizers were calculated for targeting yield of maize (45 q ha^{-1}). The nitrogen (N), phosphorus (P) and potassium (K) were provided as per the treatment details through urea, single super phosphate (SSP) and muriate of potash (MOP), respectively and FYM application was applied at the rate of 10 t ha^{-1} . Dhaincha (green manure) was sown during April month and no fertilizers were applied to it. 45-50 days old dhaincha was then incorporated into the respective plots. Sowing of maize was done 20-25 days after green manure incorporation.

2.3 Collection of Soil Samples and Soil Analysis

Individual soil samples were collected from 0-15 cm depth before maize sowing and after

Table 1. Soil test based fertilizer adjustment equations for targeted yield of maize

Fertilizer dose (kg ha ⁻¹)	Equation Without FYM	Equation With FYM
Nitrogen	$F N = 3.6 T - 0.565 SN$	$F N = 3.36 T - 0.535 SN - 0.72 FYM$
Phosphorus	$F P_2O_5 = 0.71 T - 0.975 SP$	$F P_2O_5 = 0.70 T - 0.965 SP - 0.52 FYM$
Potassium	$F K_2O = 0.64 T - 0.065 SK$	$F K_2O = 0.63 T - 0.065 SK - 0.11 FYM$

*where $F N$, $F P_2O_5$ and $F K_2O$ are fertilizer N, P_2O_5 and K_2O in kg ha⁻¹ respectively. T is the yield targeted in q ha⁻¹; SN , SP and SK are soil available N, P and K in kg ha⁻¹ respectively.

harvesting of maize crop. The soil samples were then air dried and then ground gently and sieved. A portion of the soil sample was stored at low temperature (4°C) in deep freezer for determination of biological properties of soil.

Water holding capacity of the soil was determined using Hilguard apparatus [4]. The organic carbon content was determined by using the method given by Walkley and Black [5]. Available nitrogen was determined by using alkaline potassium permanganate method [6]. Available phosphorus was extracted by using sodium bicarbonate extractant (0.5 M NaHCO₃) which was adjusted to pH 8.5 [7]. Available K in soil was determined using 1 N NH₄OAc (pH 7) [8]. Dehydrogenase activity in soil was estimated as per the procedure of Tabatabai [9]. Urease activity in soil was estimated as per the procedure given by Bremner and Douglas [10]. Soil microbial biomass carbon was determined by using chloroform fumigation extraction method as described by Jenkinson and Powlson [11].

2.4 Statistical Analysis

The experimental data was then analyzed using the statistical program STPR in a Randomized Block Design. Analysis of Variance and critical difference (CD) between treatments was calculated at 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Results

Physico-chemical, biological properties of soil and crop yield were significantly influenced by application of various organic and inorganic sources of nutrients under STCR approach. Substitution of N (either 50% or 25%) through use of green manures registered significant increase in all the physico-chemical, biological properties of soil and crop yield over control (no fertilizers).

3.1.1 Organic carbon

Organic carbon of soil varied from a minimum of 0.47 per cent under control (T1) to a maximum of 0.99 per cent under treatment receiving 75% STCR dose of N (inorganic mode) in conjugation with green manure (T5), which was significantly superior to all the other treatments except treatment receiving combined application of chemical fertilizers and organic manures using STCR approach (T4) (Table 2). STCR based use of fertilizers along with 10 tonnes FYM/ha (T4) recorded higher organic carbon by 18.67 and 41.27 per cent when compared with STCR based use of chemical fertilizers alone (T3) and recommended doses of fertilizers (T2), respectively. The treatment consisting of RDF (T2) and the treatment receiving only organic sources of nutrients (T9) recorded a significant increase of 34.04 and 44.68 per cent over control.

3.1.2 Available N

Available N in soil varied from a minimum of 112.90 kg/ha under control (T1) to a maximum of 183.98 kg/ha under treatment receiving combined application of chemical fertilizers and organic manures using STCR approach (T4), which was significantly superior to all the treatments except T5, T6 and T7 (Table 2). STCR based use of fertilizers along with 10 tonnes FYM/ha (T4) recorded higher available N by 22.22 and 29.41 per cent when compared with STCR based use of chemical fertilizers alone (T3) and recommended doses of fertilizers (T2), respectively. The treatment consisting of RDF (T2) and the treatment receiving only organic sources of nutrients (T9) recorded a significant increase of 25.93 and 37.03 per cent over control.

3.1.3 Available P

Available P in soil varied from a minimum of 13.45 kg/ha under control (T1) to a maximum of 28.95 kg/ha under treatment receiving combined application of chemical fertilizers and organic

manures using STCR approach (T4), which was significantly superior to all the other treatments except T5, T6, T7 and T2 (Table 2). STCR based use of fertilizers along with 10 tonnes FYM/ha (T4) recorded higher available P by 18.94 and 43.96 per cent when compared with STCR based use of chemical fertilizers alone (T3) and recommended doses of fertilizers (T2), respectively. The treatment consisting of RDF (T2) and the treatment receiving only organic sources of nutrients (T9) recorded a significant increase of 49.52 and 70.41 per cent over control.

3.1.4 Available K

Available K in soil varied from a minimum of 126.56 kg/ha under control (T1) to a maximum of 200.85 kg/ha under treatment receiving 75% STCR dose of N (inorganic mode) in conjugation with green manure (T5), which was significantly superior to all the other treatments except T6 (Table 2). STCR based use of fertilizers along with 10 tonnes FYM/ha (T4) recorded higher available K by 0.42 and 12.03 per cent when compared with STCR based use of chemical fertilizers alone (T3) and recommended doses of fertilizers (T2), respectively. The treatment consisting of RDF (T2) and the treatment receiving only organic sources of nutrients (T9) recorded a significant increase of 25.07 and 30.09 per cent over control (T1).

3.1.5 Water holding capacity (WHC)

Water Holding Capacity of soil varied from a minimum of 41.13 per cent under control (T1) to a maximum of 63.20 per cent under treatment receiving combined application of chemical fertilizers and organic manures using STCR approach (T4), which was significantly superior to all the other treatments (Table 3). STCR based use of fertilizers along with 10 tonnes FYM/ha (T4) recorded higher WHC by 24.21 % and 30.88 % when compared with STCR based use of chemical fertilizers alone (T3) and recommended doses of fertilizers (T2), respectively. The treatment consisting of RDF (T2) and the treatment receiving only organic sources of nutrients (T9) recorded a significant increase of 17.41 and 28.59 per cent over control.

3.1.6 Dehydrogenase activity

Dehydrogenase activity in soil varied from a minimum of 173.85 $\mu\text{gTPF/gsoil/day}$ under

control (T1) to a maximum of 223.60 $\mu\text{gTPF/gsoil/day}$ under treatment receiving 75% STCR dose of N (inorganic mode) in conjugation with green manure (T5), which was significantly at par with T4, T7, T3, T6, T8 and T9 (Table 3). STCR based use of fertilizers along with 10 tonnes FYM/ha (T4) recorded higher dehydrogenase activity by 8.09 and 13.17 per cent when compared with STCR based use of chemical fertilizers alone (T3) and recommended doses of fertilizers (T2), respectively. The treatment consisting of RDF (T2) and the treatment receiving only organic sources of nutrients (T9) recorded a significant increase of 11.79 and 14.73 per cent over control (T1).

3.1.7 Urease activity

Urease activity in soil varied from a minimum of 19.72 $\mu\text{g urea/g soil/h}$ under control (T1) to a maximum of 30.06 $\mu\text{g urea/g soil/h}$ under treatment receiving combined application of chemical fertilizers and organic manures using STCR approach (T4), which was significantly at par with T3 and T5 (Table 3). STCR based use of fertilizers along with 10 tonnes FYM/ha (T4) recorded higher urease activity by 14.38 and 19.71 per cent when compared with STCR based use of chemical fertilizers alone (T3) and recommended doses of fertilizers (T2), respectively. The treatment consisting of RDF (T2) and the treatment receiving only organic sources of nutrients (T9) recorded a significant increase of 27.33 and 11.56 per cent over control (T1).

3.1.8 Microbial biomass carbon

Microbial biomass carbon in soil varied from a minimum of 202.77 $\mu\text{g/g soil}$ under control (T1) to a maximum of 335.35 $\mu\text{g/g soil}$ under treatment receiving combined application of chemical fertilizers and organic manures using STCR approach (T4), which was significantly at par with treatment receiving 75% STCR dose of N (inorganic mode) in conjugation with green manure (T5) (Table 3). STCR based use of fertilizers along with 10 tonnes FYM/ha (T4) recorded higher microbial biomass carbon by 6.17 and 26.47 per cent when compared with STCR based use of chemical fertilizers alone (T3) and recommended doses of fertilizers (T2), respectively. The treatment consisting of RDF (T2) and the treatment receiving only organic sources of nutrients (T9) recorded a significant increase of 30.77 and 17.31 per cent over control (T1).

Table 2. Effect of integrated use of chemical fertilizers and organic manures under STCR approach on organic carbon, available N, available P and available K of soil after maize harvesting

Treatment details	OC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T ₁ : Control (no fertilizers)	0.47	112.90	13.45	126.56
T ₂ : RDF (N-150, P ₂ O ₅ -60, K ₂ O-40 kg ha ⁻¹)	0.63	142.17	20.11	158.29
T ₃ : STCR (inorganic mode)	0.75	150.53	24.33	176.59
T ₄ : STCR INM mode	0.89	183.98	28.94	177.33
T ₅ : 75% STCR dose of N (inorganic mode) + Green manure	0.99	167.25	27.41	200.85
T ₆ : 50% STCR dose of N (inorganic mode) + Green Manure	0.82	158.89	26.51	190.03
T ₇ : 75% RDN + Green Manure	0.79	163.07	25.10	169.87
T ₈ : 50% RDN + Green Manure	0.71	146.35	23.57	160.91
T ₉ : FYM + Green Manure + Intercropping with urd	0.68	154.71	22.93	164.64
SEm±	0.051	8.70	1.77	7.09
(CD = .05)	0.154	26.09	5.31	21.26

* where RDF is Recommended doses of fertilizers, RDN is recommended doses of nitrogen, STCR is Soil Test Crop Response and STCR-INM is Soil Test Crop Response-Integrated Nutrient Management.

Table 3. Effect of integrated use of chemical fertilizers and organic manures under STCR approach on WHC, DHA, MBC and urease activity of soil after maize harvesting

Treatment details	WHC (%)	DHA (µgTPF/gsoil/day)	MBC (µg/g soil)	Urease (µg urea/g soil/h)
T ₁ : Control (no fertilizers)	41.13	173.85	202.77	19.72
T ₂ : RDF (N-150, P ₂ O ₅ -60, K ₂ O-40 kg ha ⁻¹)	48.29	194.34	265.16	25.11
T ₃ : STCR (inorganic mode)	50.88	203.48	315.85	26.28
T ₄ : STCR INM mode	63.20	219.94	335.35	30.06
T ₅ : 75% STCR dose of N (inorganic mode) + Green manure	58.67	223.60	304.15	29.56
T ₆ : 50% STCR dose of N (inorganic mode) + Green Manure	56.03	202.75	272.96	24.39
T ₇ : 75% RDN + Green Manure	54.02	208.70	280.76	27.50
T ₈ : 50% RDN + Green Manure	47.87	200.10	241.76	23.72
T ₉ : FYM + Green Manure + Intercropping with urd	52.89	199.46	237.86	22.00
SEm±	1.15	8.14	10.74	1.26
(CD = .05)	3.44	24.39	32.19	3.77

* where RDF is Recommended doses of fertilizers, RDN is recommended doses of nitrogen, STCR is Soil Test Crop Response and STCR-INM is Soil Test Crop Response-Integrated Nutrient Management.

3.1.9 Grain and straw yield

The grain yield of maize was significantly influenced by application of various organic and inorganic sources of nutrients and it ranged from 17.72 to 43.75 q ha⁻¹. Highest grain yield was recorded under STCR INM (TY - 45q/ha) treatment which was significantly superior to all the treatments except 75% STCR dose of N (inorganic mode) + Green manure and STCR (inorganic mode) (TY- 45q/ha) treatment (Table

4). STCR based use of fertilizers along with 10 tonnes FYM/ha (T₄) recorded higher grain yield by 9.29 % and 34.24 % when compared with STCR based use of chemical fertilizers alone (T₃) and recommended doses of fertilizers (T₂), respectively. The treatment consisting of RDF recorded a significant increase of 83.75 % over control. Substitution of N (either 50% or 25%) through use of green manures registered significant increase in yield over control (no fertilizers). Straw yield of maize was significantly

Table 4. Effect of integrated use of chemical fertilizers and organic manures under STCR approach on grain and straw yield of maize crop

Treatment details	Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)
T ₁ : Control (no fertilizers)	17.72	36.35
T ₂ : RDF (N-150, P ₂ O ₅ -60, K ₂ O-40 kg ha ⁻¹)	32.59	54.31
T ₃ : STCR (inorganic mode)	40.03	59.73
T ₄ : STCR INM mode	43.75	66.59
T ₅ : 75% STCR dose of N (inorganic mode) + Green manure	41.13	62.02
T ₆ : 50% STCR dose of N (inorganic mode) + Green Manure	31.06	52.10
T ₇ : 75% RDN + Green Manure	35.22	55.58
T ₈ : 50% RDN + Green Manure	28.88	47.36
T ₉ : FYM + Green Manure + Intercropping with urd	26.03	46.68
SEm±	1.60	1.94
(CD = .05)	4.79	5.83

* where RDF is Recommended doses of fertilizers, RDN is recommended doses of nitrogen, STCR is Soil Test Crop Response and STCR-INM is Soil Test Crop Response-Integrated Nutrient Management.

influenced by application of various organic and inorganic sources of nutrients and it ranged from 36.35 to 66.59 q ha⁻¹. Highest straw yield was recorded under STCR INM (TY - 45q/ha) treatment which was significantly superior to all the treatments except 75% STCR dose of N (inorganic mode) + Green manure. STCR based use of fertilizers along with 10 tonnes FYM/ha (T₄) recorded higher straw yield by 11.49 % and 22.61 % when compared with STCR based use of chemical fertilizers alone (T₃) and recommended doses of fertilizers (T₂), respectively. The treatment consisting of RDF recorded a significant increase of 49.41 % over control.

3.2 Discussion

Higher physico-chemical properties of soil were observed under STCR based treatments. STCR approach helps in balanced nutrient availability by efficient utilization of nutrients from soil, fertilizer sources and synergistic effect of the conjugated use of organic as well as inorganic sources [12]. With the application of organic manures (FYM or green manuring) there was a buildup of organic carbon in the soils. In comparison to FYM, green manure was found to have multiple benefits to the soil and crop productivity. It enriches the soil with organic matter and essential nutrients. Green manure incorporation also improves soil physical, chemical and biological properties, reduces compaction of soil, increases porosity of soil, water infiltration, increases microbial activity, promotes nutrient cycling and finally enhances crop health and yield. Green manures are

therefore, also known as soil fertility building crops [13]. Green manure also reduces the nitrogen fertilizer application to the succeeding crops [14]. Higher organic carbon during decomposition enhanced the chemical reactions going on in the soil which helped in dissolution of nutrients present in soil in unavailable form to the available form which can be easily assimilated by the plant roots [15]. Organic matter also acts as a chelating agent which complexes with various nutrient ions and makes it available to plants during its entire growth period. Combined application of organic manures and fertilizers under STCR approach also helps in improvement of nutrient use efficiency, P solubilization, K availability, enhancing soil properties and ultimately maintaining soil quality [16].

Soil microbial biomass carbon and enzymatic activity was reported to be higher under treatments containing higher organic matter. Since, higher organic carbon in soil leads to greater multiplication of soil microbes which ultimately converts organically bound nutrients into inorganic form and also helps in rapid transformation and mineralization of nutrients [17]. Dehydrogenase and urease enzymes have biological significance as they helps in biological cycling of nutrients, which is affected by the microbial population in soil. Enhanced microbial activity in soil was observed under integrated use of organic and inorganic sources of nutrients. The readily available carbon fraction of FYM and green manure supported more microbial growth and increased the soil microbial biomass carbon and also enzymatic activity in soil [18].

The reason of higher grain and straw yield under STCR based approaches might be due to improved physical, chemical and biological properties of soil which ultimately lead to increased productivity [19]. Under integrated use of chemical fertilizers and organic manures, there is balanced application of nutrients and also decomposition of FYM releases various organic acids which binds the soil particles together and forms stable soil aggregates which provides favourable conditions for achieving the higher target yield [20]. In situ incorporation of green manures in the field increased the concentration of organic matter in soil. As a result, substitution of N by green manures was observed to be an alternative approach to decrease the inorganic fertilizer doses as use of green manures reduced the recommended dose of fertilizers near to 50%. Green manures contain a significant quantity of nutrients and also it helps in slow release of nutrients reserves in soil, which lead to improvement of soil health and fertility and ultimately increase in crop yield. Similar results were also reported by Pooniya & Shivay 2011 [21] and Singh and Shivay, 2013 [22].

4. CONCLUSION

It could be concluded from the above study that STCR based integrated nutrient application appears to be the best approach for maintaining soil fertility and achieving the desired level of target yield of maize crop. The conjugated use of chemical fertilizers along with green manuring was found to be a viable option for improving soil quality, sustaining crop productivity and at the same time reducing the negative impact of excessive use of chemical fertilizers on the environmental quality. It was also concluded that green manuring can substitute for about 25% of the fertilizer doses.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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