

Impact of STCR Based Fertilizer Application on Soil Chemical Properties of Rabi Onion in Inceptisols

Abstract

A field experiment for fertilizer equation validation was conducted during the Rabi season of 2022–23 under the AICRP on STCR farm, PGI farm, and AICRP on IWM farm, MPKV, Rahuri, to evaluate the effect of STCR-based fertilizer application on the soil chemical properties of Rabi onion. The experiment was laid out in a randomized block design with ten treatment combinations: Absolute Control, GRDF, As per Soil Test, STCRC target for 250 q ha⁻¹ without vermicompost, STCRC target for 300 q ha⁻¹ without vermicompost, STCRC target for 350 q ha⁻¹ without vermicompost + Biofertilizer, STCRC target for 250 q ha⁻¹ with vermicompost, STCRC target for 300 q ha⁻¹ with vermicompost, STCRC target for 300 q ha⁻¹ with vermicompost + Biofertilizer, and only 5 t ha⁻¹ vermicompost. The research findings indicated that treatment T₉ significantly increased electrical conductivity (0.24 dS m⁻¹) and soil organic carbon content (0.59%). Similarly, treatment T₉ resulted in the highest residual soil available nitrogen and phosphorus levels, measuring 199.21 kg ha⁻¹ and 16.12 kg ha⁻¹, respectively. On the other hand, the highest soil available potassium level (475.29 kg ha⁻¹) was recorded in treatment T₆, which was comparable to treatment T₉ (471.76 kg ha⁻¹). Combining vermicompost with biofertilizers (*Azospirillum* and *PSB*) boosts nutrient use efficiency, reduces losses, and improves residual nutrient content compared to treatments without them.

Keywords: STCR, Chemical Properties, Vermicompost, Biofertilizer

1. Introduction

The 'targeted yield model' is one of the practical approaches for efficient use of fertilizers. The theory of formulating optimum fertilizer recommendations for targeted yields was first given by [1] Troug and later modified by [2] Ramamoorthy as 'Inductive-cum targeted yield model'. Incorporating the Integrated Plant Nutrition System (IPNS) into this concept ensures balanced fertilization through the application of both inorganic and organic nutrient sources.

Balanced fertilization essentially involves the rational use of fertilizers and organic manures to supply plant nutrients for agricultural production. This approach aims to ensure efficient fertilization, maximize positive and synergistic interactions among various production factors, minimize adverse environmental effects and reduce nutrient losses [3].

Vermicompost, produced through the digestion of organic waste by earthworms, is a nutrient-rich resource packed with essential macro and micronutrients, plant growth regulators, vitamins and beneficial microflora. It is widely celebrated for its ability to enhance soil fertility in an environmentally sustainable way, making it a key player in promoting eco-friendly agricultural practices [4]. Compared to inorganic fertilizers, vermicompost stands out as a superior alternative due to its diverse microbial populations and high levels of enzyme activity, which significantly boost plant growth [5], [6].

Similarly, biofertilizers offer a sustainable and cost-effective solution. These products contain live microorganisms that improve soil fertility by increasing organic matter, enhancing nutrient availability and mobilizing essential nutrients within the soil [7]. Recognized for their affordability and eco-friendliness,

biofertilizers are gaining momentum in modern crop production. They work in tandem with organic matter to transform insoluble nutrients into forms that plants can readily absorb, supporting healthy growth [8].

While organic manures typically provide nutrients in smaller quantities than chemical fertilizers, they also supply growth-promoting compounds such as enzymes and hormones. These contribute not only to improved soil health and productivity but also to enhanced overall plant growth. Looking ahead, the adoption of organic manures and biofertilizers will become a cornerstone of sustainable agriculture, ensuring that crop nutrient needs are met in an environmentally responsible way.

2. Material and Method

The present STCR validation experiments were carried out in STCR farm, PGI field and AICRP on IWM field, MPKV Rahuri during the *rabi* season 2022-23. The experiment was laid out in uniform and nearly levelled land with medium deep black soil belongs to order Inceptisols. The soil is slightly alkaline, low in nitrogen and phosphorus and high in potassium which described in table 1.

Table 1. Initial Soil properties of all three locations

Sr.No.	Particulars	AICRP on STCR	PGI	AICRP on IWM
1	pH (1:2.5)	8.03	7.92	7.87
2	EC (1:2.5) (d S m ⁻¹)	0.19	0.17	0.20
3	Organic Carbon (%)	0.56	0.50	0.53
4	Available N (kg ha ⁻¹)	169	158	201
5	Available P (kg ha ⁻¹)	14	10	14
6	Available K (kg ha ⁻¹)	437	414	426

The STCR equation on *rabi* onion (Variety- N: 2-4-1) was derived by test crop trial and given below;

- i) STCR yield target equation without vermicompost

$$FN = (0.83 \times T) - (0.65 \times SN)$$

$$FP_0O_5 = (0.41 \times T) - (3.21 \times SP)$$

$$FK_2O = (0.45 \times T) - (0.18 \times SK)$$

- ii) STCR yield target equation with vermicompost (5 t ha⁻¹)

$$FN = (0.65 \times T) - (0.51 \times SN - 5.05 \text{ VC})$$

$$FP_0O_5 = (0.39 \times T) - (3.06 \times SP - 5.22 \text{ VC})$$

$$FK_2O = (0.38 \times T) - (0.15 \times SK - 4.04 \text{ VC})$$

- iii) STCR yield target equation with vermicompost (5 t ha⁻¹) and Biofertilizer (*Azospirillum* and *PSB*)

$$FN = (0.63 \times T) - (0.49 \times SN - 6.57 \text{ VC})$$

$$FP_0O_5 = (0.27 \times T) - (2.13 \text{ SP} - 5.00 \text{ VC})$$

$$FK_2O = (0.36 \times T) - (0.15 \times SK - 5.49 \text{ VC})$$

Where, F and S indicate fertilizer and soil nutrients, respectively (kg ha⁻¹), t indicates yield target (t ha⁻¹), VC indicates vermicompost (t ha⁻¹), VC + BF indicates vermicompost (t ha⁻¹) + Biofertilizer.

These relationships were further used to compute fertilizer dose for different yield targets of *rabi* onion and varying soil test values.

The experiment was laid out in randomized block design with three replications. The treatments comprised with ten treatments such as T₁-Absolute Control, T₂- GRDF, T₃- As per Soil Test, T₄ -STCRC target for 250 qt ha⁻¹ without vermicompost, T₅-STCRC target for 300 qt ha⁻¹ without vermicompost, T₆- STCRC target for 350 qt ha⁻¹ without vermicompost + Biofertilizer, T₇- STCRC target for 250 qt ha⁻¹ with vermicompost, T₈- STCRC target for 300 qt ha⁻¹ with vermicompost, T₉- STCRC target for 300 qt ha⁻¹ with vermicompost + Biofertilizer, T₁₀- Only 5 t ha⁻¹ vermicompost. For assessment of chemical properties of soil, surface representative and composite soil samples from each treatment were collected replication wise and dried in shade, pounded in wooden mortar and pestle and passed through 2 mm sieve and used for chemical analysis. Soil pH (1:2.5) was determined by potentiometric method and electrical conductivity (1:2.5) was determined by conductometric method [9]. Organic carbon in soil was determined by wet oxidation method [10]. Available N in soil was determined by alkaline permanganate method [11]. Available P in soil was determined by NaHCO₃ (0.5 M) method [12]. Available K in soil was determined by N N NH₄OAc method [13]. The data were analyzed statistically and results were interpreted by using methods suggested by Panse and Sukhatme [14].

3. Result and Discussion

3.1 Impact of STCR Based Fertilizer Application on Soil pH, Electrical Conductivity (dS m⁻¹) and Organic Carbon (%)

Soil pH measures the acidity or alkalinity of soil, reflecting the concentration of hydrogen ions (H⁺) in the soil solution. It is a critical soil property that influences various chemical, biological and physical processes within soil ecosystems. Soil pH plays a key role in plant growth, nutrient availability, microbial activity and overall soil health. In the verification trials conducted across three locations (AICRP on STCR, PGI, and AICRP on IWM) no significant differences in soil pH were observed (Table 2). However, the soil pH values showed slight numerical variations, ranging from 7.98 to 8.03 in the AICRP on STCR trial, 7.80 to 8.00 at the PGI farm, and 7.57 to 7.89 at the AICRP on IWM location.

Soil electrical conductivity (EC) measures the soil's ability to conduct electrical current, offering insights into the concentration of soluble salts and ions in the soil solution. These factors play a crucial role in plant growth and soil fertility. Pooled data on electrical conductivity (Table 2) revealed higher values in treatment T₉ (STCR target 350 q ha⁻¹ with 5 t ha⁻¹ vermicompost + biofertilizer) and treatment T₄ (STCR target 250 q ha⁻¹ without vermicompost), both recording 0.24 dS m⁻¹. Treatments T₅, T₆, T₇, and T₈ showed similar results to T₉ and T₄. In contrast, the lowest pooled electrical conductivity was observed in treatment T₁ (Absolute Control), with a value of 0.18 dS m⁻¹. The application of fertilizers and organic manures increases the concentration of soluble salts in the soil, resulting in elevated electrical conductivity, as noted by Singh *et al.* [15]. Studies by Goyal *et al.* [16] and Rajamani *et al.* [17] also highlight the influence of STCR-based fertilizer application on soil pH and electrical conductivity.

Soil organic carbon (SOC) represents the carbon stored in soil organic matter, including plant and animal residues at various stages of decomposition. It is a critical component of soil fertility, structure and overall ecosystem functioning. SOC plays a vital role in nutrient cycling, water retention, soil aggregation,

microbial activity and crop productivity. Pooled data (Table 2) showed that the highest soil organic carbon content was recorded in treatment T₉ (STCR target 350 q ha⁻¹ with 5 t ha⁻¹ vermicompost + biofertilizer) at 0.59%, while the lowest was observed in treatment T₁ (Control) at 0.47%. The results indicated that all treatments performed on par with T₉. The combined use of organic manures and fertilizers enhances soil organic carbon, primarily due to the increased organic inputs from biomass, as highlighted by Pandey and Srivastava (2021) [18]. Similar findings on the positive effects of STCR-based fertilizer application on soil organic carbon have been reported by Goyal *et al.* [16] and Venkatesh *et al.* [19].

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Table 2. Impact of STCR Based Fertilizer Application on Soil pH, Electrical Conductivity (dS m⁻¹) and Organic Carbon (%)

Tr.No	Soil pH				Electrical Conductivity (dS m ⁻¹)				Organic Carbon (%)			
	AICRP on STCR	PG Farm	AICRP on IWM	Pooled	AICRP on STCR	PG Farm	AICRP on IWM	Pooled	AICRP on STCR	PG Farm	AICRP on IWM	Pooled
T ₁	8.02	7.90	7.85	7.92	0.18	0.16	0.19	0.18	0.49	0.45	0.47	0.47
T ₂	8.03	7.89	7.67	7.86	0.21	0.18	0.18	0.19	0.60	0.53	0.48	0.54
T ₃	8.02	7.82	7.57	7.80	0.22	0.19	0.19	0.20	0.58	0.51	0.49	0.53
T ₄	8.03	7.90	7.83	7.92	0.25	0.23	0.23	0.24	0.54	0.49	0.48	0.50
T ₅	8.03	8.00	7.89	7.97	0.25	0.22	0.22	0.23	0.56	0.52	0.49	0.52
T ₆	8.01	8.00	7.81	7.94	0.28	0.21	0.21	0.23	0.58	0.53	0.52	0.54
T ₇	8.01	7.86	7.80	7.89	0.23	0.22	0.23	0.23	0.60	0.54	0.49	0.54
T ₈	8.00	7.89	7.74	7.88	0.24	0.21	0.24	0.23	0.61	0.56	0.57	0.58
T ₉	7.98	7.83	7.76	7.86	0.23	0.23	0.25	0.24	0.62	0.57	0.57	0.59
T ₁₀	8.01	7.80	7.76	7.86	0.22	0.21	0.21	0.21	0.54	0.50	0.48	0.51
S.E. (m) ±	0.04	0.07	0.08	0.06	0.01	0.01	0.005	0.01	0.03	0.01	0.02	5.60
CD @5%	NS	NS	NS	NS	0.03	0.02	0.014	0.02	0.08	0.04	0.06	0.16

3.2 Impact of STCR Approach on Soil Available Nitrogen (kg ha^{-1}), Soil Available Phosphorous (kg ha^{-1}) and Soil Available Potassium (kg ha^{-1})

Soil available nitrogen refers to the portion of nitrogen (N) in the soil that is readily accessible for plant uptake and use. As a critical nutrient for plant growth, nitrogen plays an essential role in the formation of amino acids, proteins, nucleic acids and chlorophyll. Understanding soil nitrogen levels is vital for optimizing crop nutrition, maximizing yields and managing nutrient inputs efficiently. The pooled data on soil available nitrogen (Table 3) ranged from 149.91 to 199.21 kg ha^{-1} . Treatment T_9 (STCR target 350 q ha^{-1} with 5 t ha^{-1} vermicompost + biofertilizer) was significantly superior to the absolute control treatment (T_1). Treatments T_8 (STCR target 300 q ha^{-1} with 5 t ha^{-1} vermicompost) and T_6 (STCR target 350 q ha^{-1} without vermicompost + biofertilizer) were statistically on par with T_9 . The higher doses of fertilizer applied to achieve elevated yield targets likely contributed to the increased nitrogen availability in the soil. This effect was further amplified by the inclusion of organic sources like vermicompost, which not only enhanced nutrient accumulation but also improved the soil's long-term fertility. Reddy *et al.* [20] highlighted this synergistic impact, attributing it to the combined use of farmyard manure (FYM) and inorganic fertilizers. The addition of FYM stimulated microbial growth and activity, further enhancing soil fertility, as noted by Udayakumar *et al.* [21] and Sekaran *et al.* [22].

Soil available phosphorus (P) refers to the portion of phosphorus in the soil that is readily accessible for plant uptake and use. As a vital nutrient, phosphorus plays a key role in energy transfer, photosynthesis, root development, flowering and fruiting. Understanding soil available phosphorus levels is essential for optimizing crop nutrition, maximizing yields and effectively managing nutrient inputs. The verification trials revealed that different nutrient management approaches did not significantly influence soil available phosphorus levels, except at the AICRP on IWM location (Table 3). At the AICRP on STCR and PGI farms, soil available phosphorus levels ranged from 12.15 to 16.19 kg ha^{-1} and 11.29 to 15.67 kg ha^{-1} , respectively. However, at the AICRP on IWM location, treatment T_9 (STCR target 350 q ha^{-1} with 5 t ha^{-1} vermicompost + biofertilizer) showed a significantly higher phosphorus availability (17.65 kg ha^{-1}) compared to the control treatment T_1 (12.21 kg ha^{-1}). The integrated application of organic manures and fertilizers in treatment T_9 likely enhanced phosphorus availability by minimizing nutrient losses, even after meeting crop nutrient demands. This is in line with the principles of the Integrated Plant Nutrient System (IPNS), as highlighted by Rajamani *et al.* [17]. Similar findings on the positive effects of STCR-based fertilizer applications on soil phosphorus levels were reported by Chari *et al.* [23] and Eunice *et al.* [24].

Soil available potassium (K) refers to the portion of potassium in the soil that is readily accessible for plant uptake and utilization. Potassium is a vital nutrient for plant growth and development, playing critical roles in enzyme activation, photosynthesis, water and nutrient uptake, osmoregulation and stress tolerance. Understanding soil available potassium levels is essential for optimizing crop nutrition, maximizing yields and managing nutrient inputs effectively. In the follow-up trials conducted at the AICRP on STCR and PGI locations, no significant differences were observed among treatments (Table 3). At the AICRP on STCR site, soil available potassium levels ranged from 424.67 to 459.99 kg ha^{-1} , while the PGI

trial reported levels between 410.50 and 434.00 kg ha⁻¹. However, at the AICRP on IWM location, treatment T₆ (STCR target 350 q ha⁻¹ without vermicompost + biofertilizer) recorded significantly higher soil available potassium levels (538.07 kg ha⁻¹). The elevated potassium levels in this treatment may be attributed to the interaction between higher doses of nitrogen, phosphorus and the priming effect of the initial potassium application. This interaction likely enhanced the release of potassium from native soil sources, increasing its availability for plant uptake, as suggested by Vijayakumar *et al.* [25]. Similar results on the efficiency of potassic fertilizers have been reported by Ahmed *et al.* [26] for rice in alluvial soils and by Kadu and Bulbule [27] for finger millet.

Table 3. Impact of STCR Approach on Soil Available Nitrogen (kg ha⁻¹), Soil Available Phosphorous (kg ha⁻¹) and Soil Available Potassium (kg ha⁻¹)

Tr.No	Soil Available Nitrogen (kg ha ⁻¹)				Soil Available Phosphorous (kg ha ⁻¹)				Soil Available Potassium (kg ha ⁻¹)			
	AICRP on STCR	PG Farm	AICRP on IWM	Pooled	AICRP on STCR	PG Farm	AICRP on IWM	Pooled	AICRP on STCR	PG Farm	AICRP on IWM	Pooled
T ₁	143.46	141.38	164.89	149.91	12.15	11.29	12.21	11.88	424.67	410.50	420.73	418.63
T ₂	164.74	166.71	203.84	178.43	15.13	14.84	14.52	14.83	439.27	419.14	439.47	432.63
T ₃	153.86	151.29	180.84	162.00	14.45	13.39	13.61	13.82	447.57	424.37	429.90	433.95
T ₄	160.43	154.01	181.69	165.38	13.85	14.37	14.40	14.21	443.47	427.02	427.87	432.79
T ₅	169.34	168.35	200.70	179.46	15.01	14.35	14.97	14.78	452.82	422.17	526.19	467.06
T ₆	173.53	169.57	208.02	183.71	14.68	15.67	15.69	15.35	459.99	427.81	538.07	475.29
T ₇	162.11	157.16	197.28	172.18	16.04	12.57	14.51	14.37	446.08	423.85	532.49	467.47
T ₈	183.98	177.13	213.09	191.40	15.85	13.30	16.17	15.11	451.51	420.33	530.00	467.28
T ₉	190.25	183.67	223.70	199.21	16.19	14.51	17.65	16.12	444.93	434.00	536.36	471.76
T ₁₀	146.82	144.15	168.22	153.06	12.70	12.64	16.45	13.93	427.96	405.82	423.67	419.15
S.E. (m) ±	6.02	6.45	6.45	3.67	3.24	1.20	0.87	0.89	14.94	15.60	15.87	17.92
CD @5%	17.89	19.16	19.42	10.32	NS	NS	2.59	2.64	NS	NS	47.16	53.26

4. Conclusion

The soil chemical parameters, such as soil electrical conductivity, soil organic carbon and soil available nitrogen, phosphorus and potassium were found to be significantly higher in the treatment T₉, which used vermicompost and biofertilizer. The use of vermicompost with biofertilizers (*Azospirillum* and *PSB*) increases nutrient use efficiency by reducing nutrient losses, ultimately enhancing the residual nutrient content compared to treatments without vermicompost and biofertilizers. The results indicate that the use of vermicompost and biofertilizers plays a crucial role in the IPNS-based STCR based fertilizer application.

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