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 revealed that treatment T_9 resulted in significantly higher electrical conductivity (0.24 dS m^{-1}) and soil organic carbon (0.59%). Similarly, treatment T_9 achieved the highest residual soil available nitrogen and phosphorus (199.21 and 16.12 kg ha^{-1}, respectively). However, the highest soil available potassium (475.29 kg ha^{-1}) was observed in treatment T_6, which was at par with treatment T_9 (471.76 kg ha^{-1}).

Keywords: *STCR, Soil pH, Electrical Conductivity, Nitrogen, Phosphorous and Potassium.*

1. Introduction

'Targeted yield model' is one of the practical approach for efficient use fertilizers. Theory of formulating optimum fertilizer recommendations for targeted yields was first given by [1] Troug which was further modified by [2] Ramamoorthy as 'Inductive-cum targeted yield model'. Addition of Integrated Plant Nutrition System (IPNS) to this concept ensures balanced fertilization by application of inorganic and organic sources of nutrients.

Balanced fertilization would essentially mean rational use of fertilizers and organic manures for supply of plant nutrients for agricultural production in such a manner that would ensure efficiency of fertilization, harnessing of best possible positive and synergistic interactions among the various other factors of production, least adverse effects on environment, minimum nutrient losses [3].

Vermicompost, created through the earthworm's digestion of organic waste, stands as a rich repository of macro and micronutrients, plant growth regulators, vitamins, and beneficial microflora. This organic resource is hailed for its ability to sustain soil fertility in an environmentally friendly manner, contributing to a more eco-friendly environment [4]. In contrast to inorganic fertilizers, vermicompost is viewed as a superior alternative due to its diverse microbial populations and richness in microbial and enzyme activities, greatly impacting the growth of various plants [5], [6].

Biofertilizers, another sustainable and cost-effective option, contain live microorganisms that enhance organic matter content, enrich soil fertility in cultivable lands, and aid in the conservation and mobilization of plant nutrients within the soil [7]. These eco-friendly alternatives, recognized for their affordability and effectiveness, are gaining prominence in crop production, serving as a supplement to organic matter to convert insoluble nutrients into a soluble and accessible form [8]. While organic manures carry nutrients in smaller quantities compared to chemical fertilizers, they also contain growth-promoting elements like enzymes and hormones, contributing not only to improved soil fertility and productivity but also to overall plant growth.In the future, the adoption of organic manures and biofertilizers to fulfill crop nutrient needs will become an essential practice for sustainable agriculture.

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 having 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})

$FN = (0.65 \times T) – (0.51 \times SN – 5.05\ VC)$

$FP_0O_5 = (0.39 \times T) – (3.06 \times SP – 5.22\ VC)$

$FK_2O = (0.38 \times T) – (0.15 \times SK – 4.04\ VC)$

iii) STCR yield target equation with vermicompost (5 t ha^{-1}) and Biofertilizer (*Azospirullum* and *PSB*)

$FN = (0.63 \times T) – (0.49 \times SN – 6.57\ VC)$

$FP_0O_5 = (0.27 \times T) – (2.13\ SP – 5.00\ VC)$

$FK_2O = (0.36 \times T) – (0.15 \times SK – 5.49\ VC)$

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 T_1-Absolute Control, T_2- GRDF, T_3- As per Soil Test, T_4 -STCRC target for 250 qt ha^{-1} without vermicompost, T_5-STCRC target for 300 qt ha^{-1} without vermicompost, T_6-STCRC target for 350 qt ha^{-1} without vermicompost + Biofertilizer, T_7- STCRC target for 250 qt ha^{-1} with vermicompost, T_8- STCRC target for 300 qt ha^{-1} with vermicompost, T_9- STCRC target for 300 qt ha^{-1} with vermicompost + Biofertilizer, T_{10}- 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 $NaHCO_3$ (0.5 M) method [12]. Available K in soil was determined by N N NH_4OAc 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 is a measure of the acidity or alkalinity of soil, indicating the concentration of hydrogen ions (H^+) in the soil solution. It is an essential soil property that influences various chemical, biological and physical processes in soil ecosystems. Soil pH has significant implications for plant growth, nutrient availability, microbial activity and overall soil health. All three locations of verification trials, including AICRP on STCR, PGI and AICRP on IWM, were found to have non-significant differences in soil pH (Table 2). Numerically, the soil pH ranged from 7.98 to 8.03 in the AICRP on STCR trial, from 7.80 to 8.00 at the PGI farm and from 7.57 to 7.89 in the AICRP on IWM location.

Soil electrical conductivity (EC) is a measure of the soil's ability to conduct an electrical current. It provides information about the concentration of soluble salts and ions in the soil solution, which can affect plant growth and soil fertility. The pooled data on electrical conductivity (Table 2) showed higher values in treatment T_9 (STCR target 350 q ha^{-1} with 5 t ha^{-1} vermicompost + biofertilizer) and treatment T_4 (STCR target 250 q ha^{-1} without vermicompost), both recording 0.24 dS m^{-1}. Treatments T_5, T_6, T_7 and T_8 were found at par with treatments T_9 and T_4. Comparatively, the lower pooled electrical conductivity was observed in treatment T_1 (Absolute Control) was 0.18 dS m^{-1}. Applying fertilizers and organic manure elevates the soluble salts in the soil, leading to an increase in electrical conductivity, as noted by Singh *et al.*[15]. Soil pH and electrical conductivity are influenced by STCR-based fertilizer application, as reported by Goyal *et al.* [16] and Rajamani *et al*.[17].

Soil organic carbon (SOC) refers to the carbon stored in soil organic matter, including plant and animal residues at various stages of decomposition. SOC is a fundamental component of soil fertility, structure and ecosystem functioning. It plays crucial roles in nutrient cycling, water retention, soil aggregation, microbial activity and crop productivity. In the pooled data (Table 2) the highest soil organic carbon was observed in treatment T_9 (STCR target 350 q ha^{-1} with 5 t ha^{-1} vermicompost + biofertilizer) was 0.59%, while the lowest was recorded in treatment T_1 (Control) was 0.47%. The results indicated that all treatments were at par with treatment T_9. The combined application of organic manure and fertilizers contributes to an increase in organic carbon content, primarily due to the heightened input from biomass, as noted by Pandey and Srivastava (2021) [18]. Similar findings regarding the impact of STCR-based fertilizer application on soil organic carbon have been reported by Goyal *et al*.[16] and Venkatesh *et al*. [19].

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) $\pm$	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})

The soil available nitrogen refers to the portion of nitrogen (N) in the soil that is present in forms readily accessible for plant uptake and utilization. Nitrogen is a crucial nutrient for plant growth, as it is a major component of amino acids, proteins, nucleic acids and chlorophyll. Understanding soil available nitrogen levels is essential for optimizing crop nutrition, maximizing yields and managing nutrient inputs effectively. The pooled soil available nitrogen (Table 3) was ranged in between 149.91 to 199.21 kg ha^{-1}. The treatment T_9 was observed to be significantly superior to the absolute control treatment. The 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 at par to the treatment T_9. The treatments received higher doses of fertilizer to achieve elevated targets, potentially leading to increased nitrogen availability in the soil. This effect was further enhanced by the application of organic sources, which not only augmented nutrient accumulation in the soil but also bolstered its long-term fertility, as suggested by Reddy *et al*. [20]. The enhancement in soil fertility was attributed to the inclusion of farmyard manure (FYM) alongside inorganic fertilizers, which stimulated the growth and activity of microorganisms, as indicated 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 in a form readily available for plant uptake and utilization. Phosphorus is an essential nutrient for plant growth and development, playing critical roles in energy transfer, photosynthesis, root development, flowering and fruiting. Understanding soil available phosphorus levels is crucial for optimizing crop nutrition, maximizing yields and managing nutrient inputs effectively. Different nutrient management approaches did not significantly influence the soil's available phosphorous except in AICRP at the IWM location (Table 3). The verification trials of AICRP on STCR and PGI farms were numerically ranged the soil available phosphorous was 12.15 to 16.19 and 11.29 to 15.67 kg ha^{-1}, respectively. In AICRP on IWM location was found that significantly superior result in treatment T_9- STCR target 350 q ha^{-1} with 5 t ha^{-1} Vermicompost + Biofertilizer (17.65 kg ha^{-1}) over the treatment T_1- Control (12.21 kg ha^{-1}). The integrated application of manure and fertilizer treatment revealed increased phosphorus availability, possibly due to the prevention of nutrient losses under the Integrated Plant Nutrient System (IPNS), even after fulfilling crop requirements, as noted by Rajamani *et al*. [17]. A similar result of STCR based fertilizer application on soil available phosphorous was noticed 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 in a form readily available for plant uptake and utilization. Potassium is an essential 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 crucial for optimizing crop nutrition, maximizing yields and managing nutrient inputs effectively. In follow-up trials of AICRP on STCR and PGI locations, no significant difference in treatments (Table 3). The soil available potassium ranges in AICRP on STCR location were 424.67 to 459.99 kg ha^{-1}, likewise, the PGI trial ranged between 410.50 to 434.00 kg ha^{-1}. In STCR on IWM location, the treatments T_6- STCR target 350 q ha^{-1} without Vermicompost + Biofertilizer (538.07 kg ha^{-1}) was significantly higher soil available potassium. The elevated potassium levels may be attributed to the interaction effect of higher doses of nitrogen and phosphorus, combined with the priming effect of initial potassium doses in the treated plots. This interaction might have led to the release of soil potassium, resulting in increased uptake from native soil sources by the crop, as suggested by Vijayakumar *et al.* [25]. Similarly, a similar efficiency of potassic fertilizer was reported for rice in alluvial soils by Ahmed *et al.* [26] and for finger millet by Kadu and Bulbule [27].

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 T_9, 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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