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Impact of Nutrient Management Technologies on Maize under Irrigated Conditions in Chandauli District, Uttar Pradesh

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ABSTRACT

The soil-test crop response (STCR) approach, which is currently gaining prominence for sustainable nutrient management, aims to adjust fertilizers for desired yield based on soil-test values.The STCR-based experiment was conducted for the desired maize production targets in alluvial soil of multiple locations of Persiya village in Naugharh block of Chandauli district, Uttar Pradesh during *kharif* 2019. It is important to test the developed fertilizer prescription equation to show how well technology is delivered to those who need it. A series of tests were set up in five locations in village Persiya to see how well fertilizer recommendations worked. First, the soils of the chosen area are examined for available N, P, and P. Control (T_1), farmer behaviors (T_2), the usually recommended fertilizer dosage (T_3), and STCR-based fertilizer doses (T_4 and T_5) are among the treatments for yield targets of 30 and 35 q ha^{-1}. The treatments were incorporated, cultivation procedures were followed on a consistent basis and yield of grains was recorded at harvest. The percentage increase in yield and benefit-cost ratio (B:C) were estimated using data on grain production and fertilizer dosages. The research findings revealed that the percent the accomplishment of the intended yield was within 10% fluctuation in all locations, showing the accuracy of the equations for prescribed integrated fertilizer dosages for maize. The highest percent increase in production was achieved in the yield of 35 q ha^{-1} (42.03%) followed by 30 q ha^{-1} (11.03%) beyond the prescribed fertilizer dosage (RDF). STCR 35 q ha^{-1} had the highest mean grain yield (3695.40 kg ha^{-1}). STCR 35 q ha^{-1} had the highest benefit-cost ratio (3.76), followed by STCR 30 q ha^{-1} (3.46). The established maize fertilizer prescription equations may be advised for alluvial in eastern Uttar Pradesh in order to achieve a yield target of 35 q ha^{-1}thereby resulting in greater economic yield. As a result, on tropical soils, an integrated STCR targeted yield method could prove to be the best feasible option for increasing maize productivity.

Keywords STCR, Fertilizer, Maize, B:C ratio, Yield target.

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INTRODUCTION

Maize (*Zea mays* L.) is indeed one of the most adaptive crops, with a broad range of adaptation under a variety of agro-climatic situations. Maize is frequently referred to as the "Queen of Cereals" since it has the highest genetic potential for production of all cereal crops. Maize is a widely cultivated cereal crop that is grown on approximately 150 million hectares of land in about 160 countries. The crop has a diverse range of soil, climate, and biodiversity requirements, and is grown using a variety of management practices. Maize is a significant contributor to global grain production, accounting for 36% or 782 million tonnes of the worldwide total grain production. Maize holds the third position in terms of significance among food crops in India, following rice and wheat.The crop is raised throughout the country and serves as an essential source of food for both humans and animals. According to an advance estimate, maize is raised on 8.7 M ha of land in India, primarily during the k*harif* season, accounting for 80% of the total maize cultivation area in the country. Maize occupies roughly 9% of India's national food basket, making it an essential crop for food and nutrition security. The growth rate in the area under cultivation was 2.6%, while production and productivity growth rates were 6.4% and 3.6%, respectively. This indicates that maize production has been increasing steadily in India over the years. There is a need for enhanced maize production technologies in order to satisfy the estimated demand for maize (22.73 million tonnes) by the end of the XI^{th} five-year plan (2011-12). In particular, there is a demand for maize production technologies that focus on nutrient management. This intervention is poised to augment the efficiency of maize cultivation and guarantee the attainment of maize production targets in a sustainable manner. The traditional approach of managing nutrients in the production of field crops which neglects the fertility status of soil has shown to be unsustainable over the long term (Venkatesh *et al*. 2017).There is a growing apprehension regarding the continuous reduction of non-renewable mineral reserves for fertilizers (Filippelli 2018). Long-term sustainability in field crop production requires increased fertilizer usage efficiency to combat the above issues (Boryczko *et al*. 2014). A practical and long-term solution would be site and crop-specific nutrient management that takes into consideration crop nutrient requirements, soil nutrient contributions, and fertilizer nutrient additions (Mahajan *et al*. 2013).The ubiquitous implementation of soil fertility-dependent nutrient management necessitates the availability of pertinent data and repositories for important crops across diverse agro-climatic regions. The concept of optimal fertilizer prescription based on targeted yield was initially proposed by Truog (1960) and subsequently refined by Ramamoorthy *et al*. (1967) through the development of an inductive cum targeted-yield model.Empirical evidence has demonstrated that fertilizer recommendations based on soil testing lead to optimal fertilizer utilization and preservation of soil productivity. The STCR approach is one such method that is widely used for recommending fertilizer doses based on soil contribution and expected yield levels. This approach involves soil testing to determine the nutrient level of the soil and then using this information to calculate the appropriate fertilizer dosage required to meet the crop's nutritional requirements. The utilization of the targeted yield approach has been extensively adopted since 1967 in the All India Co-ordinated Research Project (AICRP) on STCR. This method utilizes multiple regression equations to examine nutrient interactions and ascertain the most suitable fertilizer dosage for diverse crops and soils. The utilization of the targeted-yield approach offers a scientific basis for achieving equilibrium in fertilization practices, which considers both nutrients derived from external sources and those available within the soil (Gayathri *et al.* 2009). This approach takes into account various factors, such as crop variety, soil type, and environmental conditions, to provide customized fertilizer recommendations that result in optimal yields and soil fertility maintenance. By providing customized fertilizer recommendations based on soil analysis and expected crop yields. In recent years, the STCR approach has also been modified to include integrated plant nutrient supply (IPNS) systems, which take into account the utilization of both inorganic fertilizers and organic manures to meet crop nutritional requirements. Several researchers in India have conducted experiments using the STCR approach. A study conducted in the state of Uttarakhand found that the STCR approach resulted in higher maize yields and improved soil quality compared to conventional fertilizer practices (Luthra *et al*.2022). An investigation carried out in Uttar Pradesh state revealed that the adoption of the STCR method led to increased rice productivity and decreased expenses on fertilizers in contrast to traditional techniques (Singh *et al*. 2020).

MATERIALS AND METHODS

Experimental site

The study involved a field experiment that was carried out in Persiya village, Naugarh block of Chandauli district, Uttar Pradesh during the *kharif* season of 2019. The experiment was conducted at five distinct locations.

Preparation and analysis of soil samples

The soil samples obtained from each location were subjected to air-drying, grinding, and subsequent passage through a 2 mm sieve. The resulting soil was then stored in polythene bags to facilitate the analysis of various physico-chemical parameters. The pH of the soil sample was determined through the use of a pH meter in a 1:2.5 soil-water suspension, as outlined by Jackson in 1973. The electrical conductivity (EC) was measured via extraction using the Conductivity Bridge method, also described by Jackson in 1973. Organic carbon (OC) was analyzed using the wet-digestion method (Walkley and Black 1934). The quantification of nitrogen (N) availability was conducted through the alkaline potassium permanganate method, as described by Subbiah and Asija in 1956. The Olsen method, developed by Olsen *et al*. in 1954, was utilized to determine the availability of phosphorus. Additionally, the ammonium acetate method was employed to determine the availability of potassium (Hanway and Heidal 1952).

Treatments of the investigation

STCR approach

The initial soil samples in Persiya village exhibited varying levels of N, P, and K ranging from 209.25 to 210.60, 16.10 to 16.90, and 195.35 to 197.75 kg ha^{-1}, respectively. Additionally, the pH and EC values of the village were measured to be within the ranges of 7.38-7.48 and 0.41-0.48 dS m^{-1}, respectively. The STCR equation, which was developed for maize, was utilized to attain yield targets of 30 and 35 q ha^{-1}. Equations for fertilizer prescription were developed for maize cultivation in the eastern plain zone of Uttar Pradesh, specifically under the STCR-IPNMS protocol (Singh *et al*. 2015). The fertilizer adjustment equations were utilized to determine the appropriate amount of nitrogen, phosphorus, and potassium required to achieve the desired maize yield (Tables 1-3). The resulting calculations are presented below:

N (kg ha^{-1}) = 12.69*T-1.27SN-.59*ON

P (kg ha^{-1}) = 3.92*T- 0.25SP-0.67*OP

K (kgha^{-1}) = 6.25*T-0.76SK-0.39*OK

Where, T=Grain yield target in q ha^{-1}; SN, SP and SK are available N, P and K through the soil in kg ha^{-1}; ON, OP and OK are N, P and K supplied

Table 1. Initial soil fertility status of five locations of village-Persiya in Naugarh block of Chandauli district.

Locations	Farmers name	pH	EC (dS m^{-1})	OC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
1	Sri Haridas S/O Sri Khelapan	7.38	0.41	0.73	210.00	16.10	195.35
2	Smt Phoolmati W/O Sri Srinath	7.40	0.48	0.78	210.30	16.40	195.55
3	Smt Phoolkumari W/O Sri Ramnandan	7.43	0.45	0.77	210.60	16.75	195.77
4	Smt Basanti W/O Sri Somaru	7.40	0.43	0.75	209.25	16.90	196.27
5	Smt Phoolwanti W/O Sri Rajkumar	7.48	0.48	0.79	210.25	16.20	197.75

Table 2. Treatment details.

Sl. No.	Symbol	Description	Fertilizer doses (kg ha^{-1})
1	T_1	Control	(0 – 0 – 0)
2	T_2	FP-farmer's practices	(100:35:35 kg ha^{-1})
3	T_3	General recommended dose	(120:60:60 kg ha^{-1})
4	T_4	STCR-based fertilizer dose for a yield target of 30 q ha^{-1}	(114:49:39 kg ha^{-1})
5	T_5	STCR-based fertilizer dose for a yield target of 35 q ha^{-1}	(177:69:71 kg ha^{-1})

through FYM in kg ha^{-1}, respectively.

Half of the N, along with a complete dosage of P_2O_5 and K_2O, was administered as a basal application, while the remaining 50% of N was applied 30 days after sowing. All other agricultural practices were implemented periodically. The Benefit Cost Ratio (BCR) was computed to evaluate the net returns from maize cultivation, utilizing data on grain yield and fertilizer application rates. The B:C ratio was determined using the net income/total cost equation, which was computed according to standard procedures considering the cost of the agricultural yield and the associated expenses of cultivation.

RESULTS AND DISCUSSION

Grain yield

The results indicate that the grain yield ranged from 2010 to 2120 kg ha^{-1} with a mean yield of 2053.2 kg ha^{-1} under conventional farmers practices. However, when utilizing the STCR approach, a yield of 30 q ha^{-1} resulted in a range of 2888 to 2922 kg ha^{-1} with a mean yield of 2904.6 kg ha^{-1}. Similarly, the STCR approach with a yield of 35 q ha^{-1} resulted in a range of 3675 to 3707 kg ha^{-1} with a mean yield of 3695.4 kg ha^{-1} across various locations (Table 4).The implementation of STCR technology resulted in a notable increase in crop yield. Specifically, the application of 30 q ha^{-1} of STCR technology resulted in an additional mean yield of 851.4 kg ha^{-1}, which is equivalent to 8.5 q ha^{-1} over the yield achieved through traditional farmer fertilizer practices. Similarly, the application of STCR technology at a rate of 35 q ha^{-1} resulted in an additional mean yield of 1642.2 kg ha^{-1}, which is equivalent to 16.4 q ha^{-1} over the yield achieved through traditional farmer fertilizer practices (Table 4).The STCR 35 q ha^{-1} exhibited an 11.03% improvement in crop yield when compared to the recommended fertilizer dose. The results indicate a statistically significant disparity among all treatments, with the maximum mean yield observed in STCR 35 q ha^{-1}. The validity of the equations utilized to prescribe integrated fertilizer doses for maize was demonstrated in each of the five verification trials, as the percentage of the target crop yield attained was within 10%. Fertilizers used in accordance with crop requirements may account for the higher grain production recommended by STCR. Fertilizers used in a target yield method take into account both the soil's nutrient content and the needs of the crop. Perhaps the timing of the fertilizer applications coincided with the most crucial growth periods for the crops. May be additional photosynthates could have been incorporated into the grain as a result. Similar results were obtained by Jayaprakash *et al*. (2006), Kumar *et al*. (2007) and Vikram *et al*. (2015).

Among the evaluated treatments, the STCR 35

Table 3. Treatments of fertilizer doses (kg ha^{-1}) imposed under different locations of village- Persiya, Naugarh block in district Chandauli.

Treatments	Location 1			Location 2			Location 3			Location 4			Location 5		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
Control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Farmer's practice	100	35	35	100	35	35	100	35	35	100	35	35	100	35	35
GRD	120	60	60	120	60	60	120	60	60	120	60	60	120	60	60
STCR 30 q ha-1	114	49	39	114	49	39	114	49	39	114	49	39	114	49	39
STCR 35 q ha-1	177	69	71	177	69	71	177	69	71	177	69	71	177	69	71

Where, GRD-General recommended dose and STCR-Soil test crop response.

Table 4. Grain yield, net benefits and B:C ratio of maize crop under different locations of village-Persiya, Naugarh block in district Chandauli.

Treatments	Grain yield (kg ha^{-1}) locations					Mean	% increment in yield over T_2	Value of additional yield (Rs)	Cost of fertilizer (Rs)	Net benefit (Rs)	B/C ratio
	1	2	3	4	5						
T_1-0 – 0 – 0	1490	1518	1481	1496	1494	1495.8	-	-	-	-	-
T_2-100 – 35 – 35	2011	2100	2120	2010	2025	2053.2	540	10800	4626	6173	1.33
T_3-120 – 60 -60	2243	2528	2511	2616	2610	2501.6	1135	22700	7037	15662	2.23
T_4-114 – 49 – 39	2922	2888	2918	2897	2898	2904.6	1420	28400	6375	22024	3.45
T_5-177 – 69 – 71	3701	3675	3707	3687	3707	3695.4	2225	44500	9354	35146	3.76
CD at 5%	10.21	15.04	27.59	26.91	36.98	23.31	-	-	-	-	-

Note: Maize@Rs 20.00 kilogram, N@Rs 17.39 kilogram, P_2O_5@Rs 56.25 kilogram, K_2O@Rs 26.66 kilogram.
T_1-Control, T_2-Farmer's practices, T_3-GRD (General recommended dose), T_4-Target yield (30 q ha^{-1}), T_5-Target yield (35 q ha^{-1}).

q ha^{-1} (valued at Rs 35146) exhibited the greatest net benefit, while the STCR 30 q ha^{-1} (valued at Rs 22024), GRD (valued at Rs 15662), and farmer practices followed in descending order (Rs 6173). The B:C ratio was highest for STCR 35 q ha^{-1} (3.76) when compared to net benefit, with STCR 30 q ha^{-1} following closely behind (3.45). So, while STCR 35 q ha^{-1} yields more than STCR 30 q ha^{-1}, the economic return is lower (Table 4).The STCR treatments exhibit superior crop yield, net benefits, and B:C ratio compared to the control and conventional recommended dose of fertilizer treatments due to a well-balanced nutrient supply from fertilizers, optimal utilization of fertilizer nutrients in conjunction with organic sources, as well as the synergistic outcomes of the concurrent application of multiple nutrient sources, are crucial considerations for enhancing agricultural productivity (Singh 2019), (Singh *et al*. 2017).

Available nutrients in post-harvest soil

The results of the post-harvest soil test indicate that the STCR study has led to adequate accumulation and preservation of available N, P and K as compared to the standard recommended dosage and typical farmer practices. STCR plots exhibited higher post-harvest soil fertility, despite the fact that they removed more nutrients from the soil in order to achieve an increased yield.The maximum post-harvest available soil N was found in STCR for 35 q ha^{-1} in location-3, Smt Phoolkumari w/o Ramnandan (248.00 kg ha^{-1}), available soil K in location-5, Smt Phoolwanti w/o Sri Rajkumar (216 kg ha^{-1}), available soil P in location-4, Smt Basanti w/o Somaru (21.50 kg ha^{-1}) in Table 5. Nutrient accumulation was higher in STCR treatment because of the combined application of inorganic and organic sources. The physico-chemical properties of soils were improved through the application of inorganic fertilizers in combination, which may result in increased and long-term productivity (Tilahun *et al*. 2013, Singh *et al*. 2019). By adopting the STCR-IPNS methodology and administering fertilizer in a consistent manner over several years, it was possible to achieve higher profits without compromising the

Table 5. Post-harvest soil fertility status of various treatment sunder different locations of Village Persiya of Naugarh block in district Chandauli.

Treatments	Location 1			Location 2			Location 3			Location 4			Location 5		
	N	P	K	N	P	K	N	P (kg ha^{-1})	K	N	P	K	N	P	K
Control	208	17.2	202	216	17.4	193	214	17.9	199	208	18.3	200	217	17.0	195
Farmer's practice	227	16.5	187	226	18.3	188	226	18.5	189	218	19.3	184	218	18.3	188
GRD	232	17.5	197	230	19	191	229	19.8	192	228	21.5	189	226	20	191
STCR30 q ha^{-1}	240	18.8	210	234	17.5	197	242	21	216	232	23.5	194	230	22	194
STCR35 q ha^{-1}	242	20	212	240	20.5	207	248	22	214	238	25.5	206	239	24	216
CD at 5%	1.33	1.02	0.63	0.58	1.09	0.79	1.43	1.05	0.89	0.84	1.50	1.05	0.74	1.26	1.25

Where, GRD – General recommended dose and STCR-Soil test crop response.

soil's fertility (Ramamoorthy and Velayutham 2011).

CONCLUSION

The research findings indicate that the STCR targeted yield models exhibit superior performance compared to conventional recommendations in the context of maize cultivation.The study's goal of developing recommendations for the quantity of fertilizer to be used in maize cultivation is an important step towards promoting sustainable crop production. By using a specific yield equation based on soil health, farmers can optimize their use of costly fertilizer inputs while still achieving good crop yields. This holds significant importance in regions where agricultural practitioners possess restricted economic means or where the expense of fertilizers is exorbitant. In addition to promoting sustainable crop production. Additionally, it aids in mitigating the adverse effects of fertilizer application on the ecosystem. Overuse of fertilizer can lead to soil degradation, water pollution, and other environmental problems. By optimizing fertilizer use based on soil health, farmers can reduce the amount of fertilizer that they need to apply. Therefore, these measures may serve to mitigate the adverse effects on the ecosystem. Hence, it can be inferred that employing STCR-based targeted yield model could serve as viable nutrient management tactics for nutrient-responsive maize cultivation in tropical soil conditions.

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