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# Growth and productivity of wheat under soil test crop response based nutrient management in vertisols of *Vindhya plateau*

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**Abstract**
In order to evaluate the soil test crop response (STCR) based integrated nutrient management in restricted irrigated wheat under the soybean-wheat cropping system in Sagar, Madhya Pradesh, a multi-location trial was carried out in participatory method for three consecutive years during rabi 2016-17 to 2018-19. The findings showed that the maximum mean grain (3586 kg $ha^{-1}$) and stover (4684 kg $ha^{-1}$) yields of wheat were obtained using the STCR-based nutrient management through inorganic sources with biofertilizers (Azotobactor & phosphate solubilizing bacteria @ 5 kg $ha^{-1}$, potassium solubilizing bacteria @ 2.5 kg $ha^{-1}$). These yields were 84.9 and 82.8% higher than the control (Farmers practice), respectively. The grain production from STCR-based nutrient management using only chemical fertilizers was 3491 kg $ha^{-1}$, which was only 0.25% less than the desired output but noticeably greater than the yield from RDF using alone chemical fertilizers and RDF plus biofertilizers. According to the statistical analysis of the data, RDF treatments significantly increased the grain and stover yield of wheat compared to farmers' practices. In comparison to other treatments, STCR-based fertilizer nutrient management using biofertilizers and STCR-based nutrient management using chemical fertilizers alone both significantly outperformed over the control in terms of nutrient uptake. The post-harvest soil analysis revealed higher values of available P and K with STCR-based nutrient management with biofertilizers when compared to other treatments, and this difference was statistically significant over control; however, a net negative balance of 45.48, 0.28, and 21.85 kg $ha^{-1}$ in available N, P, and K was documented under farmers' practices. Maximum net return and B:C ratio (Rs. 42512 $ha^{-1}$ and 4.04), followed by RDF by chemical fertilizers alone (Rs. 40688 $ha^{-1}$ and 3.85) and minimum in FP plots (Rs. 17214 $ha^{-1}$ and 2.29), were observed in STCR-based nutrient management with biofertilizers. The study unambiguously showed how STCR-based nutrient management combined with biofertilizers can achieve the desired crop yield with conserving nutrients and enhancing soil fertility.

**Keywords:** STCR, biofertilizers, chemical fertilizers, RDF, nutrient uptake, nutrient balance, soil fertility

## Introduction
Plant-available nutrients are affected by the soil's changes in location and time since it is a living creature. Even within one to two ha paddocks, there is spatial heterogeneity in soil type, which gives farmers the opportunity to manage fertilizer inputs differently to these various agricultural regions (Betteridge *et al.* 2008) [2]. Farmers in India use excessive and indiscriminate amounts of chemical fertilizers in order to boost crop yields, yet crops need fertilizer to comprehend their expected crop yield and how to respond to nutrient applications. As there is currently a significant gap between nutrient application and nutrient mining, one of the causes of poor production is growers using fertilizer unfairly without knowing the fertility status and nutrient requirements of crops. This has a negative impact on the soil and crops, leading to nutrient toxicity and deficiency. This method not only damages the health of the soil but also causes a huge loss of farmers. (Sharma *et al.* 2016) [18]. Conventional fertilizer recommendations often include predetermined amounts of N, P, and K for large regions. Such recommendations assume that a crop's fertilizer needs are constant across time and across large regions. But due to variations in crop-growing conditions, crop and soil management, and climate, the development and requirements of a crop for supply of nutrients might differ significantly among fields, seasons, and time. Therefore, nutrient management demands a process that enables changes in the amounts of N, P, and K used to account for the crop's unique field-specific requirements for supplemental nutrients. (Singh *et al.* 2015) [19].

A crucial staple food for the nearly 2.5 billion people on the planet, wheat (*Triticum aestivum* L.) is one of the most important cereal crops cultivated worldwide. With about half of all calories in North Africa and West and Central Asia being sourced from wheat, it is the most important grain for daily consumption. India is the world's second-largest producer of wheat. (Sharma and Sendhil 2015; Sharma and Sendhil 2016; Sharma *et al.* 2015) [14, 16, 17]. Nearly 30 million hectares (14% of the world's acreage) were used to cultivate the crop that had an average yield of 3371 kg $ha^{-1}$ and produced 99.70 million tonnes of wheat (or 13.64% of the world's total production). It accounts for 36% of all food grains produced in India, assuring both food and nutrition security. (MoA & FW 2018) [10]. Increases in irrigation capacity, the use of chemical fertilizers and other agro-chemicals in a responsible manner, the introduction of high yielding cultivars, and other factors have all contributed to an inspiring rise in crop yields, notably wheat. More than one-third of this increase in food grain output is attributable to N-fertilizers alone, which account for about half of the overall increase in production. The application of the proper amount of fertilizer, one of the most expensive inputs in agriculture, is crucial for farm profitability and environmental safety. (Kimetu *et al.* 2004) [7].

One of the most efficient cropping sequences, soybean-wheat, covers 4.5 million hectares of *vertisols* in central India and has been shown to increase sustainability and production over the long term. (Potkile *et al.* 2018) [12]. Although the soybean-wheat cropping system requires plenty of nutrients, it is the most desirable sequence in terms of returns and energy efficiency (Vyas and Khandwe 2012) [22]. Based on the soil test crop response (STCR) approach and robust agronomic practices, there are several opportunities for boosting crop productivity. In the described approach, the estimated fertilizer dosages are based on fertilizer adjustment equations that were created after a substantial correlation was found between the results of the soil test and the added fertilizers. Due to the combined use of soil and plant analysis, which provides information on the real balance between applied nutrients and the nutrients that are actually currently accessible in the soil, the STCR-based recommendation idea is more measurable, accurate, and relevant. (Sharma *et al.* 2016; Singh *et al.* 2017) [15, 16, 20]. As a consequence, this study was conducted to evaluate the effects of soil test crop response based fertilizer nutrient recommendations using chemical fertilizers with integration of biofertilizers in restricted irrigated wheat under soybean-wheat crop sequence.

## Materials and Methods

To assess the impact of fertilizer recommendations based on soil test crop response (STCR) in wheat cultivated in soybean-wheat cropping sequence under limited irrigation situations in Sagar district of the *Vindhya plateau* agro-climatic zone in Madhya Pradesh, on-farm trials were planned during rabi 2016-17 to 2018-19 at 10 locations in participatory approach. The treatments details were $T_1$: Farmer's practice (as control) - NPK @ 19.5:23:0 kg $ha^{-1}$), $T_2$: RDF @ 40:20:10 kg $ha^{-1}$ NPK through chemical fertilizers, $T_3$: RDF @ 40:20:10 kg $ha^{-1}$ NPK through chemical fertilizers and biofertilizers i.e. azotobactor & phosphate solubilizing bacteria (PSB) @ 5 kg $ha^{-1}$, potassium solubilizing bacteria (KSB) @ 2.5 kg $ha^{-1}$, $T_4$: STCR based NPK application through chemical fertilizers and biofertilizers i.e. azotobactor & PSB @ 5 kg $ha^{-1}$, KSB @ 2.5 kg $ha^{-1}$ (3500 kg $ha^{-1}$ targeted grain yield) and $T_5$: STCR based NPK application through chemical fertilizers (3500 kg/ha targeted grain yield). The trial was replicated thrice in randomized block design. For a target yield of 3500 kg $ha^{-1}$, fertilizer nutrient dosages were determined using the fertilizer adjustment formulae. The fertilizer adjustment equation is given hereunder:

$$FN = 4.40\,T - 0.40\,SN,\quad FP_2O_5 = 4.00T - 4.58\,SP,\quad FK_2O = 2.53T - 0.16\,SK$$

Where FN, $FP_2O_5$ and $FK_2O$ = fertilizer dose (kg $ha^{-1}$ and SN, SP and SK = soil test values (kg $ha^{-1}$, T stands for targeted yield of the crop in kg $ha^{-1}$.

Using the above equation quantity of fertilizer nitrogen was calculated and urea (46% N) was applied for nitrogen supplement. Half of the fertilizer nitrogen was applied during sowing and remaining half at heading of the crop. Fertilizer P and K was supplemented through DAP (18:46:0) and muriate of potash (0:0:60) at the time of sowing as basal dose. The required quantity of biofertilizers (azotobactor, PSB and KSB) was applied before last ploughing prior to sowing of the crop in the respective treatments. The crop was sown in the last week of October in 2016, 2017 and 2018. Two irrigations were given at 35 and 70 days after sowing and one hand weeding was done for eradicating the weeds in the trial. The grain and stover yields were recorded at harvest. Pre-sowing and post-harvest soil samples were collected from each location and tested for available nitrogen, phosphorus, and potassium using the methods described by Subbaiah and Asija 1956 [21], Olsen *et al.* 1954 [11], and Hanway and Heidal 1952 [6], respectively. Samples of the grain and straw were taken when the crop was harvested. By using the micro kjeldhal digestion and distillation method, nitrogen, phosphorus, and potassium levels in the plant and straw samples were determined using the methods given by Amma, (1989) [1], Koenig and Johnson (1942) [8] and Black (1965) [3] respectively

The Gomez and Gomez (1984) [5] method was used to statistically examine the data. The concentrations and production of the nutrients were used to compute the absorption. Each of the treatments' net returns, incremental returns, and B: C ratios underwent economic analysis. The data reported here are mean of year wise average of the three-year study's location-specific data.

## Results and Discussion

### Growth, yield attributes and yield

Application of fertilizer based on soil test crop response (STCR) had a substantial impact on the plant's height, effective tillers $m^{-2}$, spike length, grains $spike^{-1}$, and grain weight (Table 1). The STCR based fertilizer application with biofertilizers i.e. azotobactor, phosphate solubilizing bacteria (PSB) @ 5 kg $ha^{-1}$ and potassium solubilizing bacteria (KSB) @ 2.5 kg $ha^{-1}$ recorded significantly greater plant height (94.2 cm), effective tillers (230.6), spike length (8.8 cm), grains $spike^{-1}$ (49.1) and 1000 grain weight (39.9 g) of wheat followed by STCR based nutrient application through chemical fertilizers ($T_5$) over RDF ($T_2$) and farmers practice as control ($T_1$) treatments during 2016-17 to 2018-19, respectively except plant height, effective tillers, spike length and grain weight in $T_2$ where the difference was non-significant. Soil test based fertilizer with biofertilizers application in $T_4$ resulted in an additive influence on these yield attributes. The growth and yield attributes were also significantly greater in $T_3$ (RDF @ 40:20:10 kg ha$^{-1}$ NPK through chemical fertilizers and biofertilizers i.e. azotobactor & phosphate solubilizing bacteria @ 5 kg ha$^{-1}$, potassium solubilizing bacteria @ 2.5 kg ha$^{-1}$) over control. The growth and yield attributes in $T_4$ were at par with STCR based nutrient application through chemical fertilizers ($T_5$) but remarkably higher over control. Due to improved nutrient availability to plants, integrated application of fertilizers and biofertilizers likely increased yield attributes and yield. The physical condition of the soil also improved in addition to the availability of nutrients. Singh *et al.* (2014) and Sharma *et al.* (2016) [15, 16] also noted similar results in pearl millet and wheat through integrated nutrient management.

The grain and stover yield of wheat were 3586 and 4684 kg ha$^{-1}$ in STCR based fertilizer application with biofertilizers ($T_4$) which was significantly higher against 3060 and 3972 kg ha$^{-1}$ under RDF through chemical fertilizers with biofertilizers; 2817 and 3544 kg ha$^{-1}$ in RDF through chemical fertilizers and FP plots (1939 and 2562 kg ha$^{-1}$) respectively. It was noticed that, an added grain yield of 86 kg ha$^{-1}$ was recorded in $T_4$ over the target yield of 3500 kg ha$^{-1}$. The grain and stover yield in STCR based nutrient management through chemical fertilizers ($T_5$) was recorded 3491 and 4489 kg ha$^{-1}$ which was also significantly greater over RDF through chemical fertilizers with biofertilizers, RDF through chemical fertilizers and FP plots. The grain yield recorded in $T_5$ was only 0.25% less to the targeted yield of 3500 kg ha$^{-1}$, however it was 80% higher over FP plots. Significant difference in $T_3$ (RDF through chemical fertilizers with biofertilizers), $T_2$ (RDF through chemical fertilizers) and $T_1$ (Control-FP plots) was noticed among each other with respect to grain and stover yield. In terms of grain yield, STCR-based nutrient management through the application of biofertilizers had a higher response rate (84.9%) than STCR-based nutrient management through chemical fertilizers (80%), but the harvest index did not show any discernible trends in the evaluated nutrient management practices. This may be the result of increased microbial activity, the conversion of inaccessible nutrients into accessible forms, higher nutrient usage efficiency, as well as enhanced physical, chemical, and biological characteristics created by the integrated use of biofertilizers which boost production. According to Yaduvanshi *et al.* (2013) [23], the greater wheat yield appeared to be the cumulative result of yield attributes that were supported by a balanced supply of nutrients. Similar results were reported by Sharma *et al.* (2015 & 2016) [14-18] in wheat and pearl millet crops using STCR-based nutrient management with 10 tonnes FYM ha$^{-1}$.

**Nutrient uptake and balance**

Table 2 shows the total N, P, and K uptake by wheat over a three-year period. As compared to FP plots (control), the total N, P, and K uptake was considerably increased by STCR-based fertilizer application using biofertilizers and STCR-based nutrient supplement using chemical fertilizers alone. The soil test-based fertilizer application with biofertilizers substantially boosted the total uptake of nitrogen (50.4 kg ha$^{-1}$) over the earlier treatments, which may be because N was fixed by the azotobacter and was more readily available in the soil solution. Nitrogen availability was improved and nitrogen uptake was sped up as a result of the application of nitrogen-fixing bacteria to the soil. The total uptake of P (24.9 kg ha$^{-1}$) increased significantly in STCR based fertilizer application with biofertilizers over FP plots probably due to soil application of phosphate solubilizing bacteria, which solubilized the soil fixed P and increased the P fertilizer use efficiency and higher the P uptake. According to the researchers' investigations, STCR-based nutrient management using FYM may be linked to physiological stimulation of plants rather than increased root system consequences. (Chandel *et al.* 2013; Sharma *et al.* 2016) [4, 15, 18]. The application of STCR-based fertilizers with biofertilizers had the highest phosphorus uptake, followed by STCR-based nutrient management using chemical fertilizers alone and RDF with biofertilizers. This indicates that there was greater P absorption and uptake due to the integrated application of PSB with inorganic source. 16.3 kg ha$^{-1}$ was the lowest uptake measured, and it came from the control. The STCR-based fertilizer application with biofertilizers ($T_4$) was associated with the highest K uptake (17.8 kg ha$^{-1}$) followed by the STCR-based nutrient management using chemical fertilizers alone ($T_5$) and the lowest in the control. STCR based fertilizer application treatments were found to be significantly greater in K uptake over control. Total K uptake noticeably increased in RDF with biofertilizers and RDF through chemical fertilizers as compared to farmers practice. Increased microbial activity and improvements in the physical, chemical, and biological characteristics of the soil may have contributed to root proliferation, which in turn helped to increase the absorption of water and nutrients from an improved rhizosphere zone and depth. The solubilisation of native nutrients, chelation of complex intermediate organic molecules formed during mineralization process, and their mobilization and accumulation in various plant parts may be responsible for the improved nutrient uptake using biofertilizers. Similar results were reported by Kumar *et al.* (2014) [9] and Sharma *et al.* (2016) [15, 18] in their studies on STCR based nutrient management with inorganic sources and FYM in pearl millet and wheat.

Highest negative balance of available N (45.48 kg ha$^{-1}$), P (0.28 kg ha$^{-1}$) and K (21.85 kg ha$^{-1}$) was recorded in FP plots after crop harvest. However, under STCR based nutrient management with biofertilizers, only 3.16 kg ha$^{-1}$ negative balance of N was observed, whereas available P and K increased by 4.1 and 3.46 kg ha$^{-1}$ after crop harvest. Under the STCR based nutrient management through chemical fertilizers alone, the net negative balance of 11.57 and 1.44 kg ha$^{-1}$ in available N and K was documented whereas available P increased by 2.69 kg ha$^{-1}$ after crop harvest. Negative balance of available N and K was higher in RDF with biofertilizers and RDF through chemical fertilizers alone than that of STCR based nutrient management treatments. Due to moderate level of available P in soil and application of di-ammonium phosphate @ 50 kg ha$^{-1}$ in control (FP plots) might almost met the P requirement of the crop hence very less negative P balance was recorded. These results specified that STCR based nutrient management treatments not only contributed better nutrition to crop but left the greater nutrient levels in soil in comparison to RDF with biofertilizers and RDF through chemical fertilizers alone. Similar results were reported in STCR based nutrient management in soybean by Raghav *et al.* (2019) [13].

**Economics**

The economics of wheat cultivation given in Table 3 designated that maximum net return and B:C ratio (Rs.42512 ha$^{-1}$ and 4.04) was recorded in STCR based nutrient management with biofertilizers followed by RDF through chemical fertilizers alone (Rs.40688 $ha^{-1}$ and 3.85) and minimum in FP plots (Rs.17214 $ha^{-1}$ and 2.29). In comparison to farmers' practices, RDF with biofertilizers and RDF using only chemical fertilizers yielded significantly greater net returns (Rs. 33922 and 30854 $ha^{-1}$) and BCRs (3.40 and 3.31). In comparison to RDF treatments over the control, the additional net return in STCR-based nutrient administration treatments was much higher. As a result, farmers may use the STCR technique to increase soil fertility while also increasing production and profitability. Raghav *et al.* 2019 [13] in soybean found findings that were comparable.

Based on the aforementioned results, it can be deduced that STCR-based nutrient management using biofertilizers is superior to STCR-based application of chemical fertilizer alone in that it not only allows for the achievement of the desired production but also improves soil fertility. Therefore, through its beneficial effect on nutrient supply and soil characteristics, STCR-based integrated application of fertilizers and biofertilizers can play a significant role in obtaining high yield potential of wheat under constrained irrigation conditions in soybean-wheat cropping systems.

**Table 1:** Effect of nutrient management practices on growth, yield attributes and yield of wheat (pooled data of three years)

| Treatments | Plant height (cm) | Effective tillers $m^{-2}$ | Spike length (cm) | Grains $spike^{-1}$ | 1000 grain weight (g) | Grain Yield (kg $ha^{-1}$) | % response | Stover yield (kg $ha^{-1}$) | Harvest Index |
|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 82.6 | 123.2 | 7.8 | 39.8 | 33.8 | 1939 | - | 2562 | 43.08 |
| $T_2$ | 89.5 | 181.4 | 8.2 | 44.2 | 37.7 | 2817 | 45.3 | 3544 | 44.29 |
| $T_3$ | 91.4 | 196.5 | 8.4 | 47.6 | 38.5 | 3060 | 57.8 | 3972 | 43.51 |
| $T_4$ | 94.2 | 230.6 | 8.8 | 49.1 | 39.9 | 3586 | 84.9 | 4684 | 43.36 |
| $T_5$ | 93.7 | 224.5 | 8.6 | 48.8 | 39.7 | 3491 | 80 | 4489 | 43.74 |
| SEm± | 0.93 | 1.04 | 0.1 | 0.82 | 0.81 | 2.23 | - | 3.06 | 0.23 |
| CD (P=0.05) | 5.75 | 7.14 | NS | 4.47 | 4.41 | 33.14 | - | 62.41 | NS |
| CV% | 1.8 | 0.9 | 2.1 | 3.1 | 3.7 | 0.1 | - | 0.1 | 0.9 |

**Table 2:** Nutrient uptake and balance after crop harvest in different nutrient management practices (mean of three years)

| Treatments | Total nutrient uptake (kg $ha^{-1}$) | | | Available N (kg $ha^{-1}$) | | | Available P (kg $ha^{-1}$) | | | Available K (kg $ha^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | Initial | After harvest | Nutrient balance | Initial | After harvest | Nutrient balance | Initial | After harvest | Nutrient balance |
| $T_1$ | 22.8 | 16.3 | 13.2 | 233 | 187.52 | -45.48 | 15.66 | 15.38 | -0.28 | 287.19 | 265.34 | -21.85 |
| $T_2$ | 42.1 | 21.8 | 16.3 | 233 | 207.65 | -25.35 | 15.66 | 16.45 | 0.79 | 287.19 | 279.46 | -7.73 |
| $T_3$ | 45.6 | 22.6 | 16.7 | 233 | 214.36 | -18.64 | 15.66 | 18.22 | 2.56 | 287.19 | 283.32 | -3.87 |
| $T_4$ | 50.4 | 24.9 | 17.8 | 233 | 229.84 | -3.16 | 15.66 | 19.76 | 4.10 | 287.19 | 290. 65 | 3.46 |
| $T_5$ | 47.2 | 23.5 | 17.1 | 233 | 221.43 | -11.57 | 15.66 | 18.35 | 2.69 | 287.19 | 285.75 | -1.44 |
| SEm± | 0.77 | 0.76 | 0.77 | - | 1.32 | - | - | 0.77 | - | - | 1.02 | - |
| CD (P=0.05) | 3.99 | 3.87 | 3.90 | - | 11.68 | - | - | 3.90 | - | - | 6.94 | - |
| CV% | 3.2 | 6.1 | 8.2 | - | 1.1 | - | - | 7.5 | - | - | 0.6 | - |

**Table 3:** Economic analysis of wheat cultivation in different nutrient management practices (mean of three years)

| Treatments | Cost of cultivation (Rs $ha^{-1}$) | Gross return (Rs $ha^{-1}$) | Net return (Rs $ha^{-1}$) | Incremental net return (Rs $ha^{-1}$) | Benefit cost ratio |
|---|---|---|---|---|---|
| $T_1$ | 13325 | 30539 | 17214 | - | 2.29 |
| $T_2$ | 13366 | 44220 | 30854 | 13640 | 3.31 |
| $T_3$ | 14130 | 48052 | 33922 | 16708 | 3.40 |
| $T_4$ | 14295 | 56480 | 42512 | 25298 | 4.04 |
| $T_5$ | 13968 | 54983 | 40688 | 23474 | 3.85 |

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