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Yield, profitability and nutrient uptake of wheat under soil test crop response based fertilizer application with different levels of lime in an acid Alfisol

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Abstract
An investigation was carried out to study the effect of integrated nutrient management with different levels of lime under soil test crop response based fertilizer application on yield, profitability and nutrient uptake by wheat in an acid Alfisol. The experiment was conducted during *rabi*, 2014-15 on the research farm of CSK Himachal Pradesh Agricultural University, Palampur. The treatments comprised of general recommended dose, soil test based, target yield 30 q ha^{-1} (IPNS), target yield 40 q ha^{-1} (IPNS) with three doses of lime (0, 1/10 and 1.0 LR) designated as L_0, L_1 and L_2 laid out in randomized block design. The results revealed that yield and nutrient uptake by wheat was significantly increased in both treatments where lime was applied in furrow @ 1/10 LR and by broadcast @ 1.0 LR for targeted yield of 40 q ha^{-1} (IPNS). The highest net return and B: C ratio was also found in treatment target yield of 40 q ha^{-1} (IPNS) with lime application @ 1/10 LR. Furthermore, the treatments based on STCR approach for target yield 30 and 40 q ha^{-1} with FYM under no lime recorded improvement in yield and nutrient uptake by plants as compared to soil test based and general recommended dose without FYM. The findings of present study revealed that the balanced used of chemical fertilizer in combination with lime produced highest and sustainable crop yield and its uptake of nutrients.

Keywords*:* Wheat, STCR-IPNS, Lime, FYM, Alfisol.

Introduction
Global food demand is growing rapidly, and doubling food production and sustaining food production at this level, are major challenges for global food security [1]. Wheat (*Triticum aestivum* L.) is the second most important cereal crop in Himachal Pradesh. Wheat has been cultivated in an area 0.36 million hectares with total production of 0.6 million tonnes in Himachal Pradesh. The average yield of wheat in Himachal Pradesh is only 16.7 q ha^{-1}, which is very low compared to other wheat growing states like Punjab and Haryana where yields are 48.9 and 50.30 qha^{-1} respectively [2]. The low average productivity in Himachal Pradesh might be due to high area under acidic soils and imbalance use of chemical fertilizers. Therefore, there is a need to increase its productivity of the crop in the state. Acid soils are usually excessive in soluble Al and Mn and deficient in P, Ca, Mg and Mo that may cause their reduced uptake and lead to nutrient imbalances in plants [3]. Furthermore, indiscriminate use of high analysis chemical fertilizers results in the deficiency of secondary and micronutrients in soils [4]. Therefore, in order to overcome this constraint, liming could be a worthwhile management technology.

Another side, the benefits of increased use of fertilizers in achieving higher targets of food grain production is very well established. However, practising farming with high yielding crop varieties under present fertilizer constraints due to their ever increasing prices, a viable proposition would be the adoption of economic and judicious fertilizer use and management practices so that the high investment on fertilizers is reaped adequately. The method of fertilizer recommendations based on targeted yield of the crops also called "Prescription Based Fertilizer Recommendations", avoid wide variations in soil rating limits, as it substitutes the exact values for soil available N, P and K [5]. The purpose of this study was to evaluate the STCR based target with different levels of lime on an acid Alfisol and ultimately on yield, economics and its nutrient uptake by wheat crop.

Materials and Methods
The present study was conducted during *rabi*, 2014-15 at the experimental farm of the department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. Soil of the study area was silty clay loam in texture and classified as Typic Hapludalf as per

Taxonomic system of soil classification [6]. Characteristics of the soil were as follows: pH 5.15, organic C 7.30 g kg^{-1}, available N 260 kg ha^{-1}, available P 15.7 kg ha^{-1} and available K 168 kg ha^{-1}. Twelve treatment combinations of lime and prescription based fertilizer recommendations i.e., three doses of lime (0, 1/10 and 1.0 LR) designated as L_0, L_1 and $L_2$and four doses of fertilizer; F_1-general recommended dose, F_2- soil test based, F_3- target yield 30 q ha^{-1} (IPNS), F_4- target yield 40 q ha^{-1} (IPNS) were tried in randomized block design (Table 1).

Table 1: Detail of treatments

Treatments	
T_1	General Recommended Dose
T_2	Soil Test Based
T_3	Target yield 30 q ha^{-1} (IPNS)
T_4	Target yield 40 q ha^{-1} (IPNS)
T_5	General Recommended Dose + 1/10 LR
T_6	Soil Test Based + 1/10 LR
T_7	Target yield 30 q ha^{-1} (IPNS) + 1/10 LR
T_8	Target yield 40 q ha^{-1} (IPNS) + 1/10 LR
T_9	General Recommended Dose + 1.0 LR
T_{10}	Soil Test Based + 1.0 LR
T_{11}	Target yield 30 q ha^{-1} (IPNS) + 1.0 LR
T_{12}	Target yield 40 q ha^{-1} (IPNS) + 1.0 LR

The basal dose of N, P_2O_5 and K_2O for wheat was 120:60:30. The lime requirement (LR) was determined by the buffer method[7] and the calculated lime was 12tha^{-1}. The equations used to calculate the fertilizer dose based on STCR concept:

$F\,N = 5.27\,T – 0.25\,SN – 1.06\,ON$

$F\,P_2O_5 = 4.13\,T – 0.38\,SP – 0.98\,OP$

$F\,K_2O = 2.87\,T – 0.15\,SK – 0.55\,OK$

In above equations, FN, FP_2O_5, FK_2O are doses of N, P_2O_5 and K_2O, respectively in kg ha^{-1}. T is the yield target (q ha^{-1}), SN, SP and SK are soil available N, P and K contents before sowing of the crop, respectively in kg ha^{-1}. Whereas ON, OP and OK are N, P and K supplied by FYM, respectively in kg ha^{-1}.

Sowing of wheat crop during *rabi* 2014-15, was done on 18th November, 2014. At the time of sowing of wheat, half dose of N and full dose of P and K were applied as per treatments. The remaining half dose of N applied top dressed at maximum maturing. The sources of N, P and K were urea, SSP and MOP, respectively. FYM application was made @ 5 t ha^{-1} on dry weight basis to wheat crop (HPW 236).

Plot wise samples of straw and seed were collected after the harvest, first air dried, then dried in oven for 3-4 days at 60^0 C till constant weight. The plant analysis carried out is as follows:

Table 2: Analytical methods used for plant analysis

S. No	Parameter	Method employed
1.	Nitrogen	Micro-Kjeldahl method [8]
2.	Phosphorus	Vanado-molybdo-phosphoric acid [8]
3.	Potassium	Wet digestion [9]

Results and Discussion

Grain and Straw Yield

The data relating to effect of prescription based fertilizers along with different levels of lime on wheat grain and straw yield are presented in table 3. Application of full dose of lime (1.0 LR) under the treatment for targeted yield 40 q ha^{-1} resulted a significant increase in grain yield over rest of treatments and found to be statistically at par with treatment comprising of targeted yield of 40 q ha^{-1} with lime doses of 1/10 LR. The former treatment recorded 13.9 per cent increase in grain yield over treatment comprising target yield of 40 q ha^{-1} without lime. The use of (1.0 LR) full dose of lime as per the prescription based fertilizer application for target yield 30 q ha^{-1} also significantly increased grain yield by 13.2 per cent over treatment comprising of 30 q ha^{-1} without lime. Similarly, there was significant improvement in grain yield up to 9.4 per cent in the target yield of 30 q ha^{-1} with furrow lime (1/10 LR) over target yield of 30 q ha^{-1} treatment without lime application. The treatment targeted comprising yield of 40 q ha^{-1} enhanced the grain yield of the crop by 80.5 and 101 per cent as compared to soil test based and general recommended dose, respectively.

Almost a similar trend was observed in straw yield with maximum yield recorded in plots treated with full dose of lime requirement (1.0 LR) for targeted yield of 40 q ha^{-1}, followed by the treatment of furrow lime (1/10 LR) and targeted yield of 40 q ha^{-1}. However, these treatments were found to be significant over all the other treatments. The treatment comprising targeted yield of 40 q ha^{-1} enhanced the grain yield (73.1% and 87.2%) of crop as compared to soil test based and general recommended dose. The increase in grain and straw yield might be due to the fact that the substantial increase in soil pH from 5.1 to 6.5 by liming, which increasing the availability of different nutrients especially P and also decrease the toxicity effects of Fe and Al ions in soil. The present results were in line with the findings of 10, 11, 12 and 13.

Table 3: Effect of prescription based fertilizer and different levels of lime application on yield

Treatments	Yield(q ha^{-1})		
	Grain	Straw	Total
General Recommended Dose	18.5	28.4	46.9
Soil Test Based	20.6	30.1	50.7
Target yield 30 q ha^{-}1(IPNS)	28.7	39.7	68.4
Target yield 40 q ha^{-1} (IPNS)	37.2	50.6	87.8
General Recommended Dose + 1/10 LR	21.3	34.9	56.2
Soil Test Based + 1/10 LR	22.4	35.9	58.4
Target yield 30 q ha^{-1} (IPNS) + 1/10 LR	31.4	57.5	88.9
Target yield 40 q ha^{-1} (IPNS) + 1/10 LR	41.9	78.8	120
General Recommended Dose + 1.0 LR	26.9	37.2	64.2
Soil Test Based + 1.0 LR	27.8	39.9	67.7
Target yield 30 q ha^{-1} (IPNS) + 1.0 LR	32.5	61.9	94.4
Target yield 40 q ha^{-1} (IPNS) + 1.0 LR	42.4	79.7	122
CD (P=0.05)	1.3	3.6	3.7

Comparatively, the higher grain and straw yield of the crop in targeted yield treatments with no lime application over general recommended dose and soil test based might be due to the balanced and judicious use of N, P and K fertilizer and also the fact that FYM @ 5 t ha^{-1} was added in targeted yield treatments. These results are in confirmation with the findings of 14, 15 and 16 in an experiment on wheat in an acid Alfisol of Himachal Pradesh.

Nutrient uptake by crop

The maximum uptake of nitrogen by grain under targeted yield treatment of 40 q ha^{-1} with 1.0 LR was found to be significant over rest of the treatments. The treatment comprising of targeted yield of 40 q ha^{-1} + 1.0 LR significantly increased the N uptake in grain by 3.4 and 17.2 per cent as compared to targeted yield of 40 q ha^{-1} + 1/10 LR and targeted yield of 40 q ha^{-1} alone, respectively. Nitrogen uptake by grain was higher in the target yield of 30 and 40 q

ha^{-1} with 1/10 LR treatments which was significantly better as compared to the target yield of 30 and 40 q ha^{-1} alone and the increase was by 12.8 and 13.2 per cent, respectively. Similarly, the N uptake by straw in the target yield of 30 and 40 q ha^{-1} alone was significantly better as compared to soil test based and general recommended dose. The treatments comprising of target yield of 30 and 40 q ha^{-1} with 1.0 LR significantly increased the N uptake by 71.1 and 77.2 per cent as compared to the target yield of 30 and 40 q ha^{-1} alone, respectively. The results are in accordance with the findings of 17, 18, 19 and 20.

The treatment of 40 q ha^{-1} target yield with 1.0 LR dose of lime recorded the maximum P uptake 16.3 kg ha^{-1} by grains and was found to be statistically at par with the treatment of 40 q ha^{-1} target yield +1/10 LR. The treatment comprising of targeted yield of 40 q ha^{-1} without lime significantly improved the uptake as compared to general recommended dose and soil test based and the increase in its uptake by grain were 177 and 142 per cent, respectively. Like grain P uptake, the treatments comprising of 40 kg ha^{-1} target yield with 1.0 and 1/10 lime application significantly increased the P uptake over the rest of the treatments. The uptake of P in wheat significantly increased due to lime application which may be attributed to better soil amelioration. It clearly indicated that P is fixed in the form of strengite and variscite whose concentration increase with increase in pH. Increase in Al-P and Fe-P may be explained in the light of results of 21 that solubility of these compounds increase with rise in pH, so is the action of lime to increase these P fraction. Similar results were also reported by 22.

The target yield 40 q ha^{-1} + 1.0 LR was found to be statistically at par with the treatment of target yield 40 q ha^{-1} + 1/10 LR with respect to potassium uptake by grains. Similar trend was recorded in case of straw. Potassium uptake by straw improved by 56.8 and 63.7 per cent in treatments 30 and 40 target yield + 1.0 LR as compared to the 30 and 40 q ha^{-1} target yield without limed treatments respectively. This might be due to the increased level of lime to increased leaf K content linearly. Increase in leaf K content with liming can be caused by the increase of the exchangeable Ca^{2+} level, releasing K^{+} from the exchange sites to the soil solution, as reported by 23.

Economic Analaysis

The value of produce was highest in the target yield 40 q ha^{-1} + 1.0 LR followed by the target yield 40 q ha^{-1}+1/10 LR treatment. The STCR based fertilizer application with furrow lime (1/10 LR) gave the higher net returns as compared to rest of the treatments. It has been established that band placement/incorporation of lime @ 1/10 of lime requirement along with recommended level of fertilizers every year is economical, practicable and effective. The application of lime at reduced rates with FYM was found to have good synergy as it consistently gave higher yields than when FYM was applied without lime. Similar results are in accordance with the findings of 24 and 25.

Table 4: Effect of prescription based fertilizer and different levels of lime application on N, P and K uptake by wheat

Treatments	N uptake			P uptake			K uptake		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
General Recommended Dose	33.8	15.1	48.9	4.6	3.2	7.8	5.5	23.0	28.5
Soil Test Based	38.3	16.6	54.9	5.3	3.7	9.0	6.7	25.6	32.3
Target yield 30 q ha^{-1} (IPNS)	56.7	24.4	81.1	8.8	5.9	14.8	10.6	35.0	45.5
Target yield 40 q ha^{-1} (IPNS)	78.2	32.5	110	13.0	8.6	21.6	14.5	45.3	59.7
General Recommended Dose + 1/10 LR	40.2	19.4	59.6	5.4	4.2	9.7	7.1	28.9	36.0
Soil Test Based + 1/10 LR	43.2	21.2	64.4	6.2	4.6	10.9	7.3	30.7	38.1
Target yield 30 q ha^{-1} (IPNS) + 1/10 LR	64.0	37.4	101	10.4	9.6	20.0	12.0	52.3	62.9
Target yield 40 q ha^{-1} (IPNS) + 1/10 LR	88.6	54.4	142	15.2	13.1	28.2	16.8	71.7	88.4
General Recommended Dose + 1.0 LR	52.5	22.0	74.5	7.5	5.2	12.8	9.0	32.3	41.4
Soil Test Based + 1.0 LR	54.5	24.6	79.0	8.0	6.2	14.3	9.6	35.1	44.7
Target yield 30 q ha^{-1} (IPNS) + 1.0 LR	67.0	41.9	108	10.7	10.2	20.8	12.2	54.9	68.6
Target yield 40 q ha^{-1} (IPNS) + 1.0 LR	91.7	57.6	149	16.3	14.0	30.1	17.7	74.2	91.6
CD (P=0.05)	2.7	2.8	4.1	1.0	1.5	1.7	1.1	3.6	4.3

The STCR based fertilizers under no lime application increased the net gain as compared to soil test based and general recommended dose only. The target yield 40 q ha^{-1} + 1/10 LR treatment gave highest net returns and followed by the same target with 1.0 LR. Similar types of results were also found by 26, 27 and 28.

Table 5: Effect of prescription based fertilizer under varying levels of lime on profitability of wheat

Treatments	Value of produce (Rs ha^{-1})	Cost of input (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C Ratio
General Recommended Dose	45418	20592	24826	2.21
Soil Test Based	49286	20946	28340	2.35
Target yield 30 q ha^{-1} (IPNS)	67066	34943	32123	1.92
Target yield 40 q ha^{-1} (IPNS)	86328	39078	47250	2.21
General Recommended Dose + 1/10 LR	53865	26592	27273	2.03
Soil Test Based + 1/10 LR	56138	26946	29192	2.08
Target yield 30 q ha^{-1} (IPNS) + 1/10 LR	87338	40943	46394	2.13
Target yield 40 q ha^{-1} (IPNS) + 1/10 LR	113501	45078	68423	2.52
General Recommended Dose + 1.0 LR	62963	44592	18371	1.54
Soil Test Based + 1.0 LR	66015	40946	25069	1.61
Target yield 30 q ha^{-1} (IPNS) + 1.0 LR	85331	54943	30388	1.56
Target yield 40 q ha^{-1} (IPNS) + 1.0 LR	114795	59078	55716	1.94

Sale price of wheat grain (Rs kg^{-1}) =13.00, wheat straw (Rs q^{-1}) =750, Cost of lime (Rs kg^{-1}) =5.00

Cost of fertilizer (Rs kg^{-1}) N= 11.80, P_2O_5= 65.60, K_2O= 28.00, FYM (Rs q^{-1}) = 100 General cost of cultivation without fertilizers, FYM and lime= Rs 14400 ha^{-1}

Conclusions

Thus, these results suggest that lime with combination of balanced use of chemical fertilizer and organic-FYM also increased the yield in acid soil and also increased the nutrient uptake which ultimately influenced the crop productivity of wheat crop.

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