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Alka Arya
Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture & Technology Pantnagar, Uttarakhand, India

Sobaran Singh
Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture & Technology Pantnagar, Uttarakhand, India

Pradeep Dey
Indian Institute of Soil Science, Bhopal, Madhya Pradesh, India

Correspondence
Alka Arya
Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture & Technology Pantnagar, Uttarakhand, India

Prediction of post-harvest soil test values and apparent nutrient balance after cauliflower (*Brassica oleracea* L var. botrytis) in Mollisol

Alka Arya, Sobaran Singh and Pradeep Dey

Abstract
A Field experiment was conducted at Vegetable Research Centre, G.B. Pant University of Agriculture and Technology Pantnagar, Udham Singh Nagar (Uttarakhand) during 2015-16. The experimental site was located at 29° N latitude, 79° 27' E longitudes and at an altitude of 217 m above the mean sea level. The experiment was conducted as per technical programme of All India Coordinated Research Project (AICRP) on Soil Test Crop Response (STCR) to develop Post harvest soil test values (PHSTVs), prediction equations adopting Inductive cum Targeted yield model [13], after cauliflower (*Brassica oleracea* L var. *botrytis*). The experiment was laid out in a fractional factorial design comprising twenty four treatments (21 fertilizer treatments + three controls) using pre-sowing soil test values, fertilizer doses and Curd yield and/or NPK uptake by the crop as independent variables and post-harvest soil test values as dependent variable, for developing prediction equations. Significant R^2 values (>0.67) were recorded for prediction equations which showed that these equations could be used for the prediction of post-harvest $KMnO_4$-N, Olsen-P and NH_4OAc-K. Apparent nitrogen, phosphorus and potassium balances were found 9.67%, -32.76 and –4.22%, respectively in cauliflower. Using the predicted post-harvest soil test values of cauliflower, soil test based fertilizer recommendation for desired yield targets of any succeeding crop could be made.

Keywords: Mollisol, postharvest soil test values, soil test crop response, cauliflower, prediction equation

Introduction
Soil testing is an important tool for crop production and soil fertility management. A sound soil testing program for rational and judicious fertilizer use to obtain desired crop response must be based on critical soil fertility limits of different nutrient elements in soils of the area. Soil testing is an important approach for predicting the fertility status of soil plant nutrient *viz,* nitrogen, phosphorus and potassium alone or in combination affect yield vis-a-vis nutrient uptake. Sound soil test crop response correlation studies help in making fertilizer recommendation for better yield of crop and in cropping sequence. Such studies are crop, soil and climate specific [12]. The soil test calibration and fertilizer recommendation must be based on yield which should provide significant correlation between soil test and crop response to fertilizer [14]. Soil testing has to be rechristened as soil quality assessment and it has to assume a holistic role not limited to guide fertilizer recommendation for a crop based on soil test but also for a sustainable crop production. Nutrient availability in the soil after the harvest of a crop is much influenced by the initial soil nutrient status, the amount of fertilizer nutrients added and the nature of the crop raised. To apply soil test based fertilizer recommendations, the soils are to be tested after each crop, which is not practicable. Therefore, it has become necessary to predict the soil test values after the harvest of the crop. It can be done by the development of prediction equations [12]. This provides the way for giving the fertilizer recommendations for whole cropping sequence based on initial soil test values. This is very useful because the soil of farmer's field under intensive cultivation cannot be tested for each crop for practical reasons. In present study, an attempt has been made to predict the post-harvest soil test values for cauliflower and analyzed apparent nutrient balance for next crop.

Materials and methods
A field experiment was conducted as per the technical program of AICRP on Soil Test Crop Response Correlation (STCR) at Vegetable Research Centre (VRC), G.B. Pant University of Agriculture and Technology Pantnagar, Udham Singh Nagar (Uttarakhand).

The Soil of the experimental field is moderately well to well drained and sandy loam in texture. The initial soil pH, electrical conductivity, Organic carbon, available alkaline potassium permanganate ($KMnO_4$) Nitrogen (N), Olsen phosphorus (P) and ammonium acetate (NH_4OAc) Potassium (K) were 6.58, 0.20 dSm^{-1}, 0.89%, 152.89 kg ha^{-1}, 17.21 kg ha^{-1}, and 260.61 kg ha^{-1}, respectively. Field experiment was carried out in two phases *viz.*, fertility gradient and test crop experiment as per the technical program of STCR in fractional factorial design comprising twenty four treatments and the test crop experiment with Cauliflower was conducted with four levels of N (0, 50, 100 and 150 kg ha^{-1}), P_2O_5 (0, 30,60 and 90 kg ha^{-1}) and K_2O (0, 30, 60 and 90 kg ha^{-1}) and three levels of Farm Yard Manure (FYM) (0, 10 and 20 t ha^{-1}) in Cauliflower. The pre-sowing and post-harvest soil samples were collected from each fertility strip after cauliflower and analyzed for alkaline $KMnO_4$-N (Subbiah and Asija) [18], Olsen-P (Olsen *et al.*) [10] and NH_4OAc-K (Hanway and Heidel) [4].

At harvesting of cauliflower samples (plant and curd) were collected, processed and analyzed for N, P and K contents (Jackson) [5] and total NPK uptake was computed. Crop was grown to maturity, harvested and plot wise plant and curd yields were recorded.

Development of prediction equations for post-harvest soil test values

The post-harvest soil test values were taken as dependent variable and a function of the pre sowing soil test values and the related parameters like yield/uptake and fertilizer nutrient doses as independent variables. The functional relationship is given below:

PHS = f (F, ISTV, yield / nutrient uptake)

Where, PHS = Post-harvest soil test value; F = Applied fertilizer nutrient; ISTV =Initial soil test value of available N, P and K.

Mathematical form of equation is, YPHS = a + b1F + b2ISTV + b3yield/uptake

Where, a = Absolute constant and b1, b2 and b3 = Respective regression coefficient.

Using these regression equations, the postharvest soil test values of nitrogen, phosphorus and potassium were predicted after cauliflower. An apparent nutrient balance sheet at the end of the experiment were calculated by subtracting post harvest soil test value form the initial soil test value.

Results & Discussion

Following the methodology outlined by Ramamoorthy *et al.* [12], PHSTVs prediction equations were developed for the prediction of post-harvest soil test values after the harvest of cauliflower (Table 1).

Table 1: Prediction equation of post-harvest soil nutrient based on yield and uptake of Cauliflower:

S. No	Prediction equation	R^2
1.	**Based on yield**	
	PHN = - 13.0369 + 0.9986 * SN - 0.0036 * FN - 0.0014 * Y	0.9821
	PHP = - 6.2497 + 1.0479 * SP + 0.0079 * FP - 0.0045 * Y	0.7224
	PHK = - 12.7897 + 1.0059 * SK + 0.0086 * FK - 0.0033 * Y	0.9979
2.	**Based on uptake**	
	PHN = - 13.3654 + 0.9997 * SN - 0.0076 * FN + 0.0018 * UN	0.9821
	PHP = - 5.6666 + 0.9812 * SP - 0.0093 * FP + 0.0283 * UP	0.6974
	PHK = - 13.3833 + 1.0069 * SK + 0.0037 * FK - 0.0034 * UK	0.9978

*Significant at P = 0.05, ** Significant at P = 0.01 FN, FP and FK = Fertilizer doses of N, P and K (kg ha^{-1}), respectively. SN, SP and SK = Soil test values of N, P and K (kg ha^{-1}), respectively. PHN, PHP and PHK = Post harvest soil test values of N, P and K (kg ha^{-1}), respectively; Y= Yield (q ha^{-1}); UN, UP and UK = Total uptake of N, P and K (kg ha^{-1}), respectively.

The results showed that when curd yield was used for predicting the extent of predictability for available nitrogen, phosphorus and potassium R^2 values were 98.21, 72.24 and 99.79 per cent, respectively, while, when uptake by cauliflower was considered the values were 98.21, 69.74 and 99.78 per cent for nitrogen, phosphorus and potassium respectively. Based on above prediction equations strip wise observed and predicted post-harvest soil test value ($KMnO_4$-N, Olsen-P and NH_4OAc-K kg ha^{-1}) can be calculated. This suggests that such regression equations can be used with confidence for the prediction of available N, P and K after cauliflower for optimum level of targeted yield based fertilizer recommendation for succeeding crops.

Singh *et al.* [16] reported the relationship amongst the post-harvest soil test values, fertilizer applied doses, initial soil test values and grain yield from treated plots for *kharif* maize crop. Appreciably large R^2 value were obtained from the equation. This suggests that regression equation can be used with confidence for the prediction of available N, P, K after maize for making soil test based fertilizer recommendation for succeeding crops. Similar results were also found by Subba Rao *et al.* [17], Milap-chand *et al.* [8] and Verma *et al.* [19] for the three major nutrients (N, P, K). Strip wise average of observed and predicted soil test values of nitrogen, phosphorus, potassium and the percentage deviation of the predicted post harvest soil test values from the actual soil test values is given in Table 2. The observed and predicted post-harvest soil test values were compared by Paired t- Test. The results clearly show that the deviations were quite small/very negligible and both actual and predicted soil test values of available nitrogen, phosphorus and potassium were in good agreement with each other. This test shows that that predicted and observed value were non-significant. This clearly shows the validity of the post harvest soil test value equations. The soil test values generated through this predicting equation may be utilized for soil test based fertilizer recommendation for the next crop in the crop rotation. Prediction equations were also developed by Bera *et al.* [1] in rice, Mishra *et al.* [9] for chickpea, Coumaravel *et al.* [2] for maize, Kumar *et al.* [6] for turmeric and Gangola *et al.* [3] for maize-chickpea sequence.

Table 2: Predicted and observed value of post-harvest soil test value

Particulars	Strip I		% deviation	Strip II		% deviation	Strip III		% deviation
	Observed	predicted		Observed	predicted		Observed	predicted	
Available nitrogen (kg N ha^{-1})	176.43	176.59	0.09	174.35	175.91	0.89	178.85	177.13	-0.97
Available phosphorus (kg P ha^{-1})	12.88	12.02	-7.16	10.76	11.55	6.84	13.63	13.70	0.52
Available potassium (kg K ha^{-1})	293.14	291.28	-0.64	253.97	254.09	0.046	264.07	265.81	0.66

Table 3: Strip wise range and average of soil test value and apparent nutrient balance during experiment

Particulars	Strip I		Strip II		Strip III		Whole field		Apparent Nutrient Balance %
	Initial	Post	Initial	Post	Initial	Post	Initial	Post	
Available nitrogen (kg N ha^{-1})	137.98-200.70 (160.98)	148.83-224.09 (176.43)	137.98-175.62 (160.46)	146.43-192.79 (174.35)	150.53-175.62 (161.50)	162.68-197.59 (178.85)	137.98-200.98 (160.98)	146.43-224.09 (176.54)	9.67
Available phosphorus (kg P ha^{-1})	15.01-20.93 (17.97)	8.11-16.74 (12.88)	15.01-21.33 (17.66)	8.11-14.43 (10.76)	17.77-22.12 (19.80)	11.66-15.92 (13.63)	15.01-22.12 (18.47)	8.11-16.74 (12.42)	-32.76
Available potassium (kg K ha^{-1})	254.24-339.36 (302.49)	244.89-330.01 (293.14)	99.68-342.72 (265.63)	90.33-331.13 (253.97)	104.16-365.12 (277.34)	94.81-352.14 (264.07)	99.68-365.12 (281.81)	90.33-352.14 (270.39)	-4.22

*Averages of soil test value are given in brackets.

Apparent nutrient balance

Nutrient balance in any crop based on the amount of added nutrient through fertilizer and FYM, the amount of nutrient removed by crops. However apparent nutrient balance is calculated by initial soil test value and post-harvest soil test value after harvesting of cauliflower and given in table 3.

Nitrogen of experimental field was changed from 160.98 to 176.54 kg N ha^{-1} initial to post soil test value. Average nitrogen in strip I was changed from 160.98 to 176.43 kg N ha^{-1}. While in strip II nitrogen was changed from 160.46 to 174.35 and average nitrogen in strip III was changed from 161.50 to 178.85 kg N ha^{-1}. Overall, nitrogen was increased from initial to post soil test value. Increase in available nitrogen with 100% NPK and FYM may be due to the direct addition of nitrogen through inorganic sources and FYM to the available pool of the soil. The increase in available nitrogen due to organic materials application might be also attributed to the greater multiplication of microbes caused by the addition of organic materials for the conversion of organically bound nitrogen to inorganic form.

Maragatham and Chellumutthu [7] reported that, the post-harvest soil of sunflower crop showed a significant build-up of soil nitrogen compared to the initial level ranging from 165 to 228 kg ha^{-1} due to addition of FYM. The favorable soil conditions under FYM addition might have helped in the mineralization of soil nitrogen leading to build up of higher available nitrogen. Similar results were also found by Yanthan *et al.* [20].

Phosphorus of experimental field was changed from 18.47 to 12.42 kg P ha^{-1} initial to post soil test value. Average phosphorus in strip I was changed from 17.97 to 12.88 kg P ha^{-1}. While in strip II phosphorus was changed from 17.66 to 10.76 and average phosphorus in strip III was changed from 19.80 to 13.63 kg P ha^{-1} may be due to high phosphorous fixation capacity of particular site characteristics. Potassium of experimental field changed from 281.81 to 270.39 kg K ha^{-1} initial to post soil test value. Average potassium in strip I was changed from 302.49 to 293.14 kg K ha^{-1}. While in strip II potassium was changed from 265.63 to 253.97 and average potassium in strip III was changed from 277.34 to 264.07 kg K ha^{-1}. Over all potassium was decreased from initial to post soil test value due to large amount of uptake potassium by crop and higher potassium fixation capacity of particular site characteristics.

In case of phosphorous and potassium, they were decreased from initial to post harvest soil test value because applied fertilizer is fully utilized by crops and some amount of phosphorous and potassium fix in the soil due to high phosphorous and potassium fixation capacity of experimental Soil but in case of nitrogen, it was slightly increased from initial to post harvest soil test value. On an average, well decomposed FYM contains 0.57% N, 0.32% P_2O_5 and 0.58% K_2O. When FYM is applied to soil about 100% of N, P_2O_5 and K_2O are available for the cauliflower crop, depending upon the transformation of each nutrient element in the soil matrix. The data on $KMnO_4$-N, Olsen-P and NH_4OAc-K indicated the build-up and maintenance of soil fertility due to soil test based fertilizer recommendation under NPK with FYM. Despite higher removal of nutrients, the fertility status was maintained at higher level in NPK with FYM as compared to NPK alone. This might be attributed to the prevention of losses of nutrients under NPK with FYM, even after meeting the crop needs. The findings of Pachauri and Singh [11] and Santhi *et al.* [15] also supported the results recorded in the present study.

Apparent nitrogen balance was positive (9.67%) in all soil fertility levels or strips and fertilizer treatments, but a negative P (-32.76%) and K (-4.22%) balance was noticed in cauliflower in soil test crop response. Further, these results cautioned to develop fertilizer recommendations based on crop demand for a specified yield targeted and indigenous soil nutrient supplying capacity.

Conclusion

On the basis of results summarized above, it can be concluded that the post harvest soil test values prediction equations were developed for available nitrogen, phosphorous and potassium and post-harvest soil test values were calculated from these equations. These equations clearly indicate a possibility for their use in meaningful fertilizer recommendation for the next crop. Thus, saving of cost of soil testing after each crop. The magnitude of negative balances of phosphorous and potassium was greater among the three strips. But nitrogen shows positively balanced. So, the rates of application of these two nutrients should be increased.

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