Evaluation of soil test methods for available N, P and K for french bean and maize in a mollisol

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ABSTRACT : Evaluation of the nutrient status in soil is important for nutritional, environmental, and economical aspects. The objective of this study was to evaluate suitable soil test methods so that availability indices for nitrogen (N), phosphorus (P) and potassium (K) could be assessed. Methods used were organic carbon (C) & alkaline $KMnO_4$ for available N, Olsen's-P, AB-DTPA & Mehlich-I for available P and NH^4OAc, AB-DTPA & Mehlich-I for available K. The relative suitability of these methods for a given nutrient was judged by comparison of the magnitude of R^2 values of the regression equations. Multiple regression equations of grain yield with different combinations of selected soil test methods i.e. organic C or alkaline KMnO4 for available N, Olsen's-P, AB-DTPA or Mehlich-1 for available P and neutral normal NH_4OAc, AB-DTPA or Mehlich-1 for available K in soil, fertilizer levels and their interactions were carried out for both french bean and maize crops. The highest value of R^2 0.686** (Significant at P = 0.01) for french bean and 0.659** for maize were found with alkaline $KMnO_4$, Olsen's and NH4OAc methods and it showed that combination of these three methods was found more promising and superior over rest other methods.

Key words: Available N, available P, available K, french bean, maize, mollisol, soil test method

Simple correlation coefficients between soil test values for one nutrient and crop yield may not give correct results when there is a variation in more than one nutrient for both soil and applied nutrients in field conditions, due to interaction effects of soil and applied nutrients. Therefore, multiple regression analysis of all three macro nutrients (NPK) at a time can be used as an alternative approach to evaluate the suitability of soil test methods.

The relative suitability of different soil test methods for a given nutrient was judged by comparison of the magnitude of R^2 values of the regression equations obtained by alternatively one method each time, keeping the methods of other nutrients constant. Generally, the R^2 values above 0.66 are taken as indication of good fit, 0.45 to 0.65 as moderate fit, and below 0.45 as poor fit of the equation (ICAR, 1974). Velayutham *et al.* (1985) evaluated various soil test methods for their suitability under field conditions. Mosi and Lakshminarayanan (1985) reported that such a screening procedure is useful in selecting the most appropriate testing procedure.

MATERIALS AND METHODS

Field experiment was carried out during 2013-14 in two phases *viz.*, fertility gradient stabilizing and test crop experiment as per the technical programme of STCR at D_7 block of Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar (29° N latitude and 79° 3' E longitude). In first phase, experimental field was divided into three equal strips and graded doses of N, P and K fertilizers (*i.e.* three levels $N_0P_0K_0$, $N_1P_1K_1$ and $N_2P_2K_2$) applied and sorghum was grown as an exhaust crop to create fertility gradient. In second phase of the experiment, each strips was divided into 24 (23 treatments + 1 control) equal sized (3 m × 3 m) plots, resulting in total of 72 plots. Treatments comprised of various selected combinations of four levels of N (0, 60, 120 and 180 kg ha^{-1} for french bean and 0, 40, 80 and 120 kg ha^{-1} for maize), four levels of P (0, 35, 70 and 105 kgP_2O_5 ha^{-1} for french bean and 0, 30, 60 and 90 kg P_2O_5 ha^{-1} for maize) and four levels of K (0, 25, 50 and 75 kg K_2O ha^{-1} for french bean and 0, 20, 40 and 60 kg K_2O ha^{-1} for maize), three levels of FYM (0, 5 and 10 t ha^{-1} for both crops). In french bean half of nitrogen, total phosphorus, total potash and total dose of FYM were broadcasted as basal and remaining half of nitrogen was applied as top dressing at 30 days after sowing, whereas in maize one-third of nitrogen and total quantity of phosphorus, potash and FYM were applied as basal and remaining two third of nitrogen was applied in two equal splits *i.e.* one third at knee high stage and one third at tasseling stage. Different fertility levels were randomly distributed in each of the three strips for each crop. Before application of basal dose of fertilizers to each crop, representative surface (0-15 cm) soil samples were collected and analyzed by organic carbon (Walkley and Black, 1934) and alkaline $KMnO_4$ (Subbiah and Asija, 1956) for available N, Olsen's extraction method (Olsen *et al*., 1954), AB-DTPA (Soltanpour and Schwab, 1977) and Mehlich-1 (Korcak and Fanning, 1978) for available P and neutral normal NH_4OAc (Hanway and Hiedal, 1952), AB-DTPA (Soltanpour and Schwab, 1977) and Mehlich-1 (Korcak and Fanning, 1978) for available K.

After application of the treatments in each plot of the strip, french bean ('Pant Anupama') was grown followed by maize ('Amar'), following standard agronomic practices. Both crops were harvested and plot-wise grain yield was recorded after maturity. Multiple regression equations of grain yield with different combinations of selected soil test methods i.e. organic C or alkaline $KMnO_4$ for available N, Olsen's-P, AB-DTPA or Mehlich-1 for available P and neutral normal NH_4OAc, AB-DTPA or Mehlich-1 for available K in soil, fertilizer levels and their interactions were carried out for both french bean and maize crops.

RESULTS AND DISCUSSION

The coefficient of determination values (R^2) was calculated for french bean and maize and presented in Table 1. The equations accounted for different magnitude of variability in grain yield as a function of different combinations of soil test methods. The extent of variability of each method is evident by the relative value of coefficients in the equations. The percentage of variability accounted for grain yield was 0.520** to 0.686** for french bean and 0.441** to 0.659** for maize.

The R^2 values obtained for french bean and maize by different combination of soil test methods indicated that combination of all methods were highly significant under this particular soil and climatic conditions. The highest value of R^2 in both crops (0.686** for french bean and 0.659** for maize) were found with alkaline $KMnO_4$, Olsen's and NH_4OAc methods. These showed that combination of these three methods was found more promising and superior over rest combinations for both crops. These observations are in accordance with the findings reported by Dhawan *et al.* (1992) and Prasad (1994).

Among the individual methods, the alkaline $KMnO_4$ had R^2 values of 0.686** and 0.659** and it was 0.677** and 0.643** in case of organic carbon for french bean and maize, respectively, when Olsen's P was used for available P and ammonium acetate K for available K estimation. Alkaline $KMnO_4$ method was found superior to organic C as indicated by higher R^2 values for both crops in Mollisol.

The R^2 values for different methods (Olsen's P, AB-DTPA P and Mehlich-I P) of available P estimation was 0.686** for Olsen's P, 0.678** AB-DTPA P and 0.683** for Mehlich-I P in case of french bean. While, for maize the R^2 values of Olsen's P was 0.659**, AB-DTPA P 0.652** and Mehlich-I P 0.654** when alkaline $KMnO_4$ method for available N and ammonium acetate method for available K were used. Olsen's method in both the crops was superior to rest two methods as a measure of available P as indicated by higher R^2 values.

The R^2 values for different methods of available K estimation was determined by keeping methods for estimation of rest two nutrients (alkaline $KMnO_4$ method for available N and Olsen's method for available P) constant. The neutral normal NH_4OA_C K with higher R^2 value (0.686**) was found superior to the rest two methods i.e. AB-DTPA (0.578**) and Mehlich-I (0.591**) for french bean. Similarly, in case of maize, neutral normal NH_4OA_C with more R^2 value (0.659**) than AB-DTPA K (0.631**) and Mehlich-I (R^2 = 0.652**) was found superior. These results are in accordance with the findings reported by Dhawan *et al.* (1992) and Prasad (1994). The significant positive correlation of Olsen's extractable P with yield and uptake of crops was also observed by Sharma and Parmar (1998). The highest universality of NH_4-acetate soil test over Mehlich-3 for K in relation to the plant was proved by Matula (2009) in his experiment. Pande (2010) also reported the superiority of Olsen's and NH_4OAc methods over AB-DTPA and Mehlich-I for available P and K.

From the above observation it can be suggested that alkaline $KMnO_4$ for soil available N, Olsen's method for soil available P and neutral ammonium acetate method for soil available K can be taken as indices for determining available N, P and K in Mollisol of Uttarakhand.

Table 1: Multiple regression equations between possible combinations of soil test values, fertilizer doses & their interactions and grain yield of french bean and maize

Multiple regression equations for french bean	R^2	Indices used
Y = -2.2324 + 2.2961 * SN - 0.0990 * SP + 0.0445 * SK + 0.0384 * FN - 0.1038 * FP + 0.0012 * FK - 0.0001 * FN^2 - 0.0004 * FP^2 - 0.0006 * FK^2 - 0.0046 * FNSN + 0.0087 * FPSP + 0.0003 * FKSK	0.677**	Organic carbon Olsen's-P NH_4OAc-K
Y = -3.2339 - 4.1687 * SN + 0.4183 * SP + 0.0291 * SK + 0.0119 * FN - 0.0281 * FP - 0.0455 * FK - 0.0001 * FN^2 - 0.0012 * FP^2 + 0.0001 * FK2 + 0.0375 * FNSN + 0.0053 * FPSP + 0.0006 * FKSK	0.604**	Organic carbon Olsen's-P AB-DTPA-K
Y = -3.0373 - 4.7119 * SN + 0.3848 * SP + 0.0322 * SK + 0.0096 * FN - 0.0429 * FP + 0.0044 * FK - 0.0001 * FN^2 - 0.0011 * FP^2 + 0.0002 * FK2 + 0.0416 * FNSN + 0.0059 * FPSP + 0.0000 * FKSK	0.614**	Organic carbon Olsen's-P Mehlich-I-K
Y = -2.6534 + 2.8792 * SN - 0.1131 * SP + 0.0448 * SK + 0.0388 * FN - 0.1129 * FP - 0.0102 * FK - 0.0001 * FN^2 - 0.0000 * FP^2 - 0.0007 * FK^2 - 0.0055 * FNSN + 0.0108 * FPSP + 0.0004 * FKSK	0.671**	Organic carbon AB-DTPA-P NH_4OAc-K
Y = -5.2209 + 2.6843 * SN + 0.6256 * SP - 0.0020 * SK + 0.0277 * FN + 0.0098 * FP - 0.1343 * FK - 0.0001 * FN^2 - 0.0011 * FP^2 - 0.0001 * FK^2 - 0.0031 * FNSN + 0.0057 * FPSP + 0.0015 * FKSK	0.520**	Organic carbon AB-DTPA-P AB-DTPA-K
Y = -7.4198 + 1.5271 * SN + 0.5552 * SP + 0.0320 * SK + 0.0246 * FN - 0.0054 * FP - 0.0086 * FK - 0.0001 * FN^2 - 0.0012 * FP^2 + 0.0001 * FK^2 + 0.0048 * FNSN + 0.0066 * FPSP + 0.0001 * FKSK	0.533**	Organic carbon AB-DTPA-P Mehlich-I -K
Y = 0.2030 + 1.6329 * SN - 0.3394 * SP + 0.0527 * SK + 0.0313 * FN - 0.1932 * FP + 0.0142 * FK - 0.0001 * FN^2 - 0.0007 * FP^2 - 0.0007 * FK^2 + 0.0082 * FNSN + 0.0163 * FPSP + 0.0003 * FKSK	0.676**	Organic carbon Mehlich-I-P NH_4OAc-K
Y = 0.6976 - 3.1454 * SN + 0.3736 * SP - 0.0015 * SK + 0.0027 * FN - 0.0999 * FP - 0.1144 * FK - 0.0001 * FN^2 - 0.0013 * FP^2 - 0.0001 * FK^2+ 0.0458 * FNSN + 0.0114 * FPSP + 0.0014 * FKSK	0.527**	Organic carbon Mehlich-I-P AB-DTPA-K
Y = -1.7263 - 4.0410 * SN + 0.3227 * SP + 0.0314 * SK + 0.0002 * FN - 0.1121 * FP - 0.0006 * FK - 0.0001 * FN^2 - 0.0015 * FP^2 + 0.0001 * FK2 + 0.0520 * FNSN + 0.0122 * FPSP + 0.0001 * FKSK	0.541**	Organic Carbon Mehlich-I-P Mehlich-I-K
Y = -2.4511 + 0.0326 * SN - 0.1901 * SP + 0.0329 * SK + 0.0517 * FN - 0.1250 * FP 0.0354 * FK - 0.0001 * FN^2 - 0.0007 * FP^2 - 0.0006 * FK^2 - 0.0002 * FNSN + 0.0109 * FPSP + 0.0005 * FKSK	0.686**	Alk.$KMnO_4$-N Olsen's-P NH_4OAc-K
Y = -6.4625 + 0.0434 * SN + 0.1361 * SP + 0.0228 * SK + 0.0542 * FN - 0.1111 * FP - 0.0646 * FK - 0.0000 * FN^2 - 0.0016 * FP^2 + 0.0001 * FK^2 - 0.0002 * FNSN + 0.0114 * FPSP + 0.0007 * FKSK	0.621**	Alk.$KMnO_4$-N Olsen's-P AB-DTPA-K
Y = -5.4487 + 0.0452 * SN + 0.1108 * SP + 0.0132 * SK + 0.0538 * FN - 0.1179 * FP - 0.0436 * FK - 0.0000 * FN^2 - 0.0015 * FP^2 - 0.0001 * FK^2 - 0.0002 * FNSN + 0.0112 * FPSP + 0.0005 * FKSK	0.629**	Alk.$KMnO_4$-N Olsen's-P Mehlich-I-K
Y = -2.8279 + 0.0259 * SN - 0.1092 * SP + 0.0312 * SK + 0.0428 * FN - 0.0909 * FP - 0.0456 * FK - 0.0001 * FN^2- 0.0002 * FP^2 - 0.0007 * FK^2 - 0.0001 * FNSN + 0.0098 * FPSP + 0.0006 * FKSK	0.678**	Alk.$KMnO_4$-N AB-DTPA-P NH4OAc-K
Y = -8.0132 + 0.0541 * SN + 0.3663 * SP - 0.0040 * SK + 0.0414 * FN - 0.0140 * FP - 0.1179 * FK + 0.0000 * FN^2 - 0.0012 * FP^2 - 0.0002 * FK^2 - 0.0002 * FNSN + 0.0077 * FPSP + 0.0014 * FKSK	0.578**	Alk.$KMnO_4$-N AB-DTPA-P AB-DTPA-K
Y = -7.7961 + 0.0579 * SN + 0.2787 * SP + 0.0004 * SK + 0.0450 * FN - 0.0385 * FP - 0.0712 * FK + 0.0000 * FN^2 - 0.0012 * FP^2 - 0.0003 * FK^2 - 0.0002 * FNSN + 0.0090 * FPSP + 0.0008 * FKSK	0.591**	Alk.$KMnO_4$-N AB-DTPA-P Mehlich-I-K
Y = -0.8581 + 0.0285 * SN - 0.3318 * SP + 0.0379 * SK + 0.0439 * FN - 0.1741 * FP - 0.0247 * FK - 0.0001 * FN^2 - 0.0007 * FP^2 - 0.0007 * FK^2 - 0.0001 * FNSN + 0.0155 * FPSP + 0.0005 * FKSK	0.683**	Alk.$KMnO_4$-N Mehlich-I-P NH_4OAc-K
Y = -4.5690 + 0.0543 * SN + 0.0913 * SP - 0.0029 * SK + 0.0396 * FN - 0.1288 * FP - 0.0998 * FK + 0.0000 * FN^2 - 0.0016 * FP^2 - 0.0002 * FK^2 - 0.0002 * FNSN + 0.0143 * FPSP + 0.0013 * FKSK	0.580**	Alk.$KMnO_4$-N Mehlich-I-P AB-DTPA-K
Y = -4.7096 + 0.0587 * SN + 0.0396 * SP + 0.0000 * SK + 0.0439 * FN - 0.1415 * FP - 0.0642 * FK + 0.0000 * FN^2 - 0.0015 * FP^2 - 0.0004 * FK^2 - 0.0002 * FNSN + 0.0147 * FPSP + 0.0008 * FKSK	0.594**	Alk.$KMnO_4$-N Mehlich-I-P Mehlich-I-K

Multiple regression equations for maize	R^2	Indices used
$Y = -14.5994 + 8.6443 * SN + 0.4226 * SP + 0.1650 * SK + 0.1065 * FN + 0.0669 * FP + 0.4714 * FK - 0.0002 * FN^2 - 0.0008 * FP^2 + 0.0011 * FK^2 - 0.0998 * FNSN - 0.0015 * FPSP - 0.0027 * FKSK$	0.643**	Organic carbon Olsen's-P NH_4OAc-K
$Y = 0.0075 + 9.2853 * SN + 1.3101 * SP - 0.0381 * SK + 0.1044 * FN + 0.2814 * FP + 0.0455 * FK - 0.0002 * FN^2 - 0.0020 * FP^2 + 0.0005 * FK^2 - 0.0934 * FNSN - 0.0099 * FPSP - 0.0003 * FKSK$	0.594**	Organic carbon Olsen's-P AB-DTPA-K
$Y = 9.8545 + 8.5742 * SN + 1.3352 * SP - 0.1179 * SK + 0.0931 * FN + 0.3186 * FP - 0.2938 * FK - 0.0002 * FN^2 - 0.0021 * FP^2 - 0.0008 * FK^2 - 0.0761 * FNSN - 0.0110 * FPSP + 0.0031 * FKSK$	0.611**	Organic carbon Olsen's-P Mehlich-I-K
$Y = -15.2786 + 8.6917 * SN + 0.3517 * SP + 0.1815 * SK + 0.1034 * FN + 0.0717 * FP + 0.4721 * FK - 0.0002 * FN^2 + 0.0006 * FP^2 + 0.0010 * FK^2 - 0.0928 * FNSN - 0.0049 * FPSP - 0.0026 * FKSK$	0.639**	Organic carbon AB-DTPA-P NH_4OAc-K
$Y = 4.6720 + 9.8531 * SN + 1.3729 * SP - 0.0683 * SK + 0.0755 * FN + 0.2722 * FP - 0.0947 * FK - 0.0002 * FN^2 + 0.0013 * FP^2 + 0.0002 * FK^2 - 0.0514 * FNSN - 0.0185 * FPSP + 0.0013 * FKSK$	0.556**	Organic carbon AB-DTPA-P AB-DTPA-K
$Y = 8.1310 + 9.6156 * SN + 1.3472 * SP - 0.0854 * SK + 0.0746 * FN + 0.2788 * FP - 0.2370 * FK - 0.0002 * FN^2 + 0.0012 * FP^2 - 0.0009 * FK^2 - 0.0474 * FNSN - 0.0182 * FPSP + 0.0027 * FKSK$	0.565**	Organic carbon AB-DTPA-P Mehlich-I -K
$Y = -11.1677 + 11.5825 * SN - 0.3220 * SP + 0.2201 * SK + 0.1330 * FN - 0.3499 * FP + 0.5648 * FK - 0.0002 * FN^2 - 0.0002 * FP^2 + 0.0010 * FK^2 - 0.1310 * FNSN + 0.0177 * FPSP - 0.0032 * FKSK$	0.642**	Organic carbon Mehlich-I-P NH_4OAc-K
$Y = 7.7587 + 11.4372 * SN + 1.0207 * SP - 0.0791 * SK + 0.0705 * FN + 0.0321 * FP - 0.0911 * FK - 0.0003 * FN^2 - 0.0013 * FP^2 + 0.0003 * FK^2 - 0.0284 * FNSN + 0.0026 * FPSP + 0.0012 * FKSK$	0.441**	Organic carbon Mehlich-I-P AB-DTPA-K
$Y = 12.8826 + 10.6945 * SN + 1.0482 * SP - 0.1149 * SK + 0.0638 * FN + 0.0950 * FP - 0.3164 * FK - 0.0003 * FN^2 - 0.0014 * FP^2 - 0.0011 * FK^2 - 0.0168 * FNSN + 0.0002 * FPSP + 0.0034 * FKSK$	0.456**	Organic Carbon Mehlich-I-P Mehlich-I-K
$Y = -14.9927 + 0.0697 * SN + 0.3930 * SP + 0.1296 * SK + 0.1650 * FN + 0.0580 * FP + 0.3434 * FK + 0.0001 * FN^2 - 0.0020 * FP^2 + 0.0009 * FK^2 - 0.0008 * FNSN + 0.0015 * FPSP - 0.0019 * FKSK$	0.659**	Alk.$KMnO_4$-N Olsen's-P NH4OAc-K
$Y = -9.0800 + 0.0956 * SN + 1.0235 * SP - 0.0038 * SK + 0.1883 * FN + 0.1986 * FP + 0.1028 * FK + 0.0002 * FN^2 - 0.0032 * FP^2 + 0.0005 * FK^2 - 0.0010 * FNSN - 0.0031 * FPSP - 0.0008 * FKSK$	0.631**	Alk.$KMnO_4$-N Olsen's-P AB-DTPA-K
$Y = 4.0417 + 0.0990 * SN + 1.0276 * SP - 0.1200 * SK + 0.1874 * FN + 0.2088 * FP - 0.3186 * FK + 0.0002 * FN^2 - 0.0031 * FP^2 - 0.0012 * FK^2 - 0.0010 * FNSN - 0.0035 * FPSP + 0.0034 * FKSK$	0.652**	Alk.$KMnO_4$-N Olsen's-P Mehlich-I-K
$Y = -16.2795 + 0.0641 * SN + 0.3269 * SP + 0.1545 * SK + 0.1526 * FN + 0.1128 * FP + 0.3548 * FK + 0.0001 * FN^2 - 0.0003 * FP^2 + 0.0007 * FK^2 - 0.0007 * FNSN - 0.0050 * FPSP - 0.0019 * FKSK$	0.650**	Alk.$KMnO_4$-N AB-DTPA-P NH4OAc-K
$Y = -6.5882 + 0.0969 * SN + 1.0771 * SP - 0.0172 * SK + 0.1531 * FN + 0.2393 * FP + 0.0242 * FK + 0.0002 * FN^2 - 0.0003 * FP^2 + 0.0000 * FK^2 - 0.0009 * FNSN - 0.0124 * FPSP + 0.0003 * FKSK$	0.590**	Alk.$KMnO_4$-N AB-DTPA-P AB-DTPA-K
$Y = 1.9071 + 0.1024 * SN + 1.0410 * SP - 0.0900 * SK + 0.1611 * FN + 0.2314 * FP - 0.2571 * FK + 0.0002 * FN^2 - 0.0002 * FP^2 - 0.0014 * FK^2 - 0.0009 * FNSN - 0.0120 * FPSP + 0.0031 * FKSK$	0.604**	Alk.$KMnO_4$-N AB-DTPA-P Mehlich-I-K
$Y = -12.3558 + 0.0713 * SN - 0.2188 * SP + 0.1821 * SK + 0.1716 * FN - 0.2507 * FP + 0.4212 * FK + 0.0000 * FN^2 - 0.0012 * FP^2 + 0.0006 * FK^2 - 0.0008 * FNSN + 0.0153 * FPSP - 0.0022 * FKSK$	0.654**	Alk.$KMnO_4$-N Mehlich-I-P NH4OAc-K
$Y = -8.8053 + 0.1352 * SN + 0.6253 * SP - 0.0036 * SK + 0.1882 * FN - 0.0437 * FP + 0.0874 * FK + 0.0002 * FN^2 - 0.0025 * FP^2 - 0.0001 * FK^2 - 0.0011 * FNSN + 0.0088 * FPSP - 0.0003 * FKSK$	0.521**	Alk.$KMnO_4$-N Mehlich-I-P AB-DTPA-K
$Y = 2.6575 + 0.1376 * SN + 0.6767 * SP - 0.1122 * SK + 0.1894 * FN + 0.0087 * FP - 0.3068 * FK + 0.0002 * FN^2 - 0.0021 * FP^2 - 0.0019 * FK^2 - 0.0011 * FNSN + 0.0059 * FPSP + 0.0036 * FKSK$	0.543**	Alk.$KMnO_4$-N Mehlich-I-P Mehlich-I-K

Where, Y = Grain yield (q ha^{-1}); SN, SP, SK = Alk. $KMnO_4$-N, Olsen's-P & Amm. Ac.- K (kg ha^{-1}), respectively. FN, FP & FK= Fertilizer nitrogen (kg N ha^{-1}), phosphorus (kg P ha^{-1}) and potassium (kg K ha^{-1}), *Significant at P = 0.05 , ** Significant at P = 0.01

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