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Evaluation of critical limits of potassium in soil for upland paddy grown on shrink-swell soils

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Abstract
The critical limits of potassium in soil for upland paddy was determined through a pot culture experiment with shrink-swell soils. The samples of eighteen different locations were collected having low (<125 kg K_2O ha^{-1}), medium (125-250 kg K_2O ha^{-1}) and high (>250 kg K_2O ha^{-1}) potassium status. The present investigation was carried out in Factorial Completely Randomized Design with two treatments (*viz.* 0 and 50 kg K_2O ha^{-1}) and two replications. The paddy crop was harvested at 100 per cent flowering. The critical limits of potassium in soil were worked out according to method of Cate and Nelson (1965 and 1971).
The critical limit of potassium in soil for paddy plant was found 264.22 kg K ha^{-1} by graphical method of (Cate and Nelson, 1965) and 268.80 kg K ha^{-1} by statistical method of (Cate and Nelson, 1971), respectively. The results indicated that, soil containing less than 268.80 kg K ha^{-1} potassium at 100 per cent flowering, respond to application of potash fertilizers.

Keywords: Potassium, critical limits, upland paddy, shrink-swell soil

Introduction
Rice (*Oryza sativa* L.) is a major *Kharif* crop of India. Rice is foremost cereal crop of the world and is the staple food of over 60 per cent of the world's population. In India, particularly Southern and Western India, rice is the main constituent of the daily diet. Rice cultivation in India is traditionally confined to the areas of high rainfall, where it is grown under lowland conditions. But with the use of irrigation resources and introduction of high yielding cultivars, rice is being cultivated under upland conditions in nontraditional areas in Maharashtra. Upland rice is grown on soils that are aerobic or oxidized for the greater part of the growing season (Ponnamperuma, 1975) [3].
Potassium (K), one of the three major essential plant nutrients acts as a master cation of the plant nutrient and involves in many physiological and biochemical functions of plant growth and yield processes. A concept of critical limit of nutrients was introduced by Ulrich (1959) [6] and Smith (1962) [4]. However, the graphical method (Cate and Nelson, 1965) [1] and later the statistical approach given by (Cate and Nelson, 1971) [2] are being widely used for establishment of critical limit of a nutrient. Critical limit is the level of soil available nutrient above which that nutrient is no longer a primary limiting factor. Critical limits in soils and plants helps for making fruitful recommendations to specific crops in a typical soil. It is the limit which isolates the deficient plants or soils from the non-deficient ones. Deficiency symptoms, nutrient concentration, nutrient uptake, percentage yield and response of plants to applied nutrients are the common parameters used for establishing the critical limits. The response of plant nutrients either in terms of growth or yield is the best criteria. Critical limits varies depending on the soil types, crop and varieties, soil test methods and seasonal variations. According to the rating low, medium and high categories for potassium are <125, 125-250 and >250 Kg K_2O ha^{-1} respectively. However as per this rating almost all black soils having high clay content, showing high availability of potassium in soil. But even though most of the crops shows positive response to potassium application. There is ambiguity in potassium rating, so to confirm specific rating for available potassium in shrink-swell soils, the study of critical limit of potassium is necessary.

Material and methods
A pot culture experiment was conducted in wire house of Division of Soil Science and Agricultural Chemistry, College of Agriculture, Kolhapur during *kharif* season 2012 to

evaluate the critical limits of potassium in soil for upland paddy (*viz*. Bhogawati) grown on shrink-swell soils. The material and standard methods employed in the present investigation are as under.

Climate and weather
The College of Agriculture, Kolhapur comes under the Sub-montane Zone, with average annual rainfall is 1057 mm.

Soil samples
The soils used for filling the earthen pots with low, medium and high potassium status were collected from 18 different locations of College of Agriculture, Kolhapur Farm. The collected soils of different potassium status were dried in shade and sieved through 2 mm sieve. The sieved soils were used for filling the earthen pots and determination of available potassium. Then the soils were categorized into low, medium and high in respect of its available 'K' content. Out of 18 locations, soil samples from six locations were in the category of low available potassium content (<125 kg K_2O ha^{-1}), Six were from medium available potassium content (125-250 kg K_2O ha^{-1}) and six in high available potassium content (>250 kg K_2O ha^{-1}).

Experimental layout
The present investigation was carried out in Factorial Completely Randomized Design. Treatments comprise two levels of potassium (0 and 50 kg K_2O ha^{-1}) through source of Muriate of potash (MOP) and were replicated twice.

Filling of pots
The 72 pots were filled with 10 kg of soil and moisture was maintained to field capacity with deionized water.

Fertilizers application
The recommended dose of N, P and K for paddy (100:50:50 N: P_2O_5: K_2O kg ha^{-1}) was calculated on per ten kilogram soil basis and two levels of potash (0 and 50 kg K_2O ha^{-1}) were taken for experimental purpose. All fertilizers quantity including potash fertilizer were doubled in pot culture experiment.

Harvesting
The rice plants were harvested at 110 DAS (at 100 per cent flowering stage). The plants were harvested with almost care and labeled them.

Determination of critical limits
The critical limits of potassium for soil were determined by using standard procedure as suggested by Cate and Nelson by graphical (1965) [1] and statistical method (1971).

Establishment of critical limit of potassium by graphical method

1. The scatter diagram of percentage yield (Y-axis) v/s soil test value (X-axis) were plotted on arithmetic paper. The range in values on the Y-axis will always be 0 to 100 per cent, whereas the range for value on the X-axis was varying with the soil test procedure, the particular soil studied and the nutrient involved.
2. A piece of clear plastic having roughly one and one-half the dimension of the graph was cut out for use as an overlay. A pair of intersecting perpendicular lines are drawn on the overlay with black India ink in such a way that it was divided into four sectors having area of roughly the same relative size. The signs of these quadrants were then labeled with black India ink.
3. The overlay was moved about horizontally and vertically on the graph always with the two lines parallel to the two axes on the graph, until the points in the negative quadrants were at a minimum.
4. The position of the lines on the overlay with respect to the axes of the graph was transferred to the graph by making marks on the edges of the graph. The two intersecting lines were then drawn lightly on the graph with pencil. The point where the vertical line crosses the X-axis was defined as the critical soil test level.

Establishment of critical limit of potassium by statistical method
The steps followed for calculation of critical level of potassium by statistical approach as suggested by Cate and Nelson (1971) [2] were as follows.

1. The initial soil test values of potassium were arranged in ascending order.
2. The per cent dry matter yield was written against each soil test potassium value.
3. The correction factor (C.F.) and total corrected sum of squares (T.C.S.S.) were calculated from per cent dry matter yield by using following formulae.

i) $C.F. = \frac{(\Sigma Y)^2}{n} = \frac{\Sigma (Y_1 + Y_2 + Y_3 + \ldots\ldots Y_n)^2}{n}$

ii) $T.C.S.S. = \Sigma Yi^2 - C.F.$
$= \Sigma (Y_1 + Y_2 + Y_3 + \ldots\ldots Y_n)^2 - C.F.$

Where,
Y= per cent dry matter yield
n = total number of observations

4. The data were grouped into two groups i.e. if the total number of observations are 'n' then data was grouped as (p, n-p), (p + 1, n-P+1) e.g. if n = 15 then the data is grouped as (2, 13) (3, 12) ……… (13, 2)

5. A table with following columns were prepared
i) Last value of soil available nutrient.
ii) Plant available K included in population 1st

i.e. $= \frac{P_1 + P_2 \ldots\ldots\ldots P_n}{P}$

iii) Combine sum of square of deviation from mean of population 1st i.e. C.S.S.I.
Here total of all values of population 1st was made
$C.S.S.I. = \Sigma P_1^2 + P_2^2 \ldots\ldots + Pn^2 - \Sigma\frac{(P_1 + \ldots\ldots\ldots Pn)}{n}$

iii) If Kn was the number of observations in population, IInd then mean relative yield in population IInd

$= \frac{K_1 + K_2 + \ldots\ldots + K_n}{n}$

v) Combined sum of squares of deviation from mean of population IInd (CSSII). Here total of all values of population IInd was made i.e. (K_1+ K_2 + ……. + Kn)

$C.S.S.I. = \Sigma K_1^2 + K_2^{2+} \ldots\ldots + Kn^2 - \Sigma\frac{(K_1 + \ldots\ldots\ldots Kn)^2}{n}$

vi) Postulated critical level (split between the two population) i.e. P.C.L. was calculated as

$$PCL = \frac{\text{last value in I}^{st}\text{ population + value in II}^{nd}\text{ population}}{2}$$

$$vii)\ R^2 = \frac{TCSS - CSSI - CSSII}{TCSS}$$

The concentration having highest R^2 is the critical concentration.

The critical level of Potassium in soil were determined by following statistical approach as suggested by Cate and Nelson (1971) [2].

Result and discussion

A pot culture experiment was conducted in wire house at the Division of Soil Science and Agricultural Chemistry, College of Agriculture, Kolhapur during *kharif* season 2012. The experimental results are presented and discussed under the appropriate heading in this chapter.

Establishment of critical limits of potassium in soil by graphical method

The critical limits of potassium in soil from the normal soils were determined, which can be employed to forecast the need for potassium fertilization. In view of the discrepancies in soil test crop response data in calculating the fertilizer requirement, Cate and Nelson (1965) [1] suggested the need for more adequate representation of the relationship between soil test values and Bray's per cent yield, which further developed into graphical method for establishing critical limits of potassium in soil.

Critical limits of potassium in soil

The data on soil available potassium, dry matter yield of paddy plant at 0 and 50 kg K_2O ha^{-1}, and Bray's per cent yield are presented in Table 1.

In the graphical method as suggested by Cate and Nelson (1965) [1] yield obtained in the experiment was converted into Bray's per cent yield and was calculated as follows.

$$\text{Bray's percent yield} = \frac{\text{Yield without potassium}}{\text{yield with optimum potassium}} X100$$

The soils selected for this study contained available potassium in the range of 78.40 to 358.40 kg ha^{-1}. The dry matter yield of paddy without potassium (K_0) and with potassium (K_{50}) ranged from 27.85 to 37.49 g pot^{-1} and 37.88 to 53.72g pot^{-1}, respectively. The calculated Bray's per cent yield ranged from 67.84 to 73.52. After plotting the Bray's percent yield v/s soil available potassium, the critical limits were determined.

A cross was placed over the data and moved until the upper left and lower right quadrant have a minimum number of points. The critical value was read from the X-axis where the vertical line intersects it. The established critical limits of potassium for soil were depicted in Fig. 1. Thus, according to graphical method, scatter diagram indicated 264.22 kg K ha^{-1} as critical limit of potassium in soil, below which the response to potassium application to soil may be expected in case of paddy crop.

Establishment of critical limits of potassium in soil by statistical method

The soil test values were often divided into two or more classes for the purpose of making fertilizer recommendations. However, the basis for different classes such as low, medium and high potassium status were often subjective or arbitrary. In the graphical approach the dividing line between two categories were drawn approximately and thus the subjectivity was involved in superimposing the vertical and horizontal lines on a scatter diagram. Therefore, in order to overcome this, a statistically sound method for setting class limits was suggested by Cate and Nelson (1971) [2]. A mathematical model has been developed for partitioning soil analysis correlation data into two sets i.e. responsive and non-responsive soils as per method suggested by Cate and Nelson (1971) [2].

Critical limit of potassium in soil by statistical method

Soil test data obtained from the experiment on paddy crop was subjected to the statistical method for computing critical level of potassium in soil as suggested by Cate and Nelson (1971) [2] which presented in Table 2.

The threshold value for soil available potassium can be isolated by considering the highest R2 value with corresponding postulated critical value for paddy crop which can be identified as 268.80 kg K ha-1. Thus, it showed that paddy crop grown on soils containing available potassium below the defined threshold value may respond to the applied potassium on shrink-swell soils (Vertisol) of Sub montane Zone.

Similar results were reported by Subba Rao and Reddy (2005) in which the critical limit of potassium for paddy crop was 120 mg K kg-1 in alluvial soils of Uttar Pradesh.

Table 1: Effect of potassium application on dry matter yield and its corresponding Bray's per cent yield of upland paddy.

Sr. No.	Soil avail. K (kg ha^{-1})	Dry matter yield (g pot^{-1}) Potassium levels (kg ha^{-1})		Bray's per cent yield
		K_0	K_{50}	
1.	78.40	27.85	37.88	73.52
2.	89.60	31.25	45.98	67.96
3.	100.80	31.35	46.08	68.03
4.	100.80	33.90	49.78	68.09
5.	100.80	31.58	46.35	68.13
6.	100.80	30.80	43.19	71.31
7.	145.60	34.69	50.72	68.39
8.	145.60	34.45	49.62	69.42
9.	156.80	34.86	51.33	67.91
10.	190.40	35.13	51.78	67.84
11.	190.40	35.90	52.32	68.61
12.	201.60	36.47	52.86	68.99
13.	268.80	36.11	52.24	69.12
14.	268.80	36.85	52.32	70.43
15.	280.00	37.30	52.89	70.52
16.	336.00	37.56	53.57	70.11
17.	336.00	37.39	53.27	70.18
18.	358.40	37.49	53.72	69.78

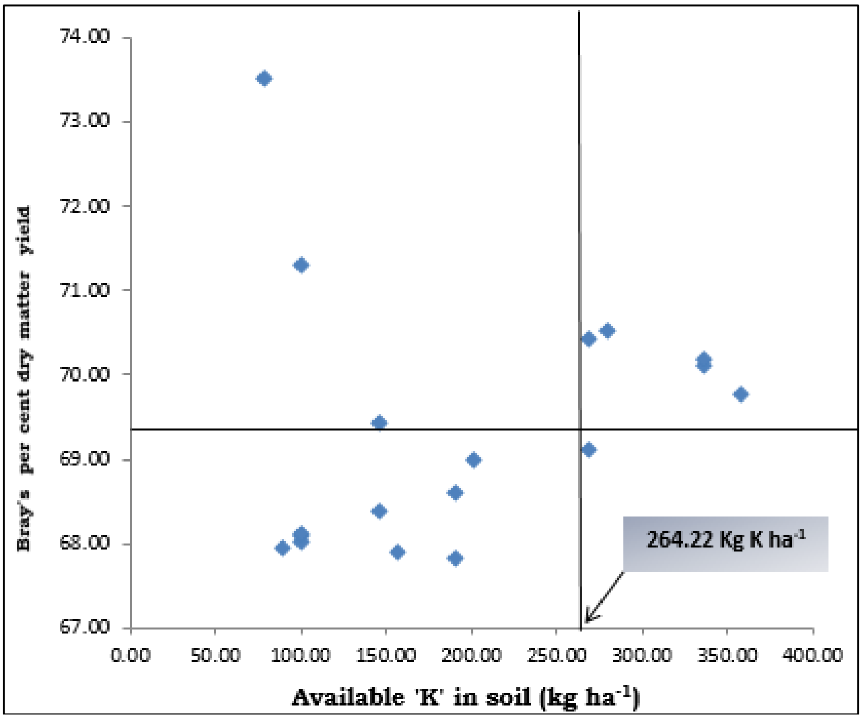

Fig 1: Scatter diagram for Bray's per cent yield of upland paddy v/s available 'K' in soil.

Table 2: Critical limit of soil potassium by statistical method (Cate and Nelson, 1971) [2].

Sr. No.	Soil available K (Kg ha^{-1}) population-1	Bray's per cent yield	Last value in population-1	Mean Bray's per cent yield in population-1	Corrected SS of deviations from mean of population-1	Mean Bray's per cent yield in population-2	Corrected SS of deviations from mean of population-2	Postulated critical limit	R^2 for Postulated critical limit
1	78.40	73.52							
2	89.60	67.96	89.6	70.74	15.43	69.18	18.19	95.20	0.1145
3	100.80	68.03	100.8	69.84	20.32	69.25	16.80	100.80	0.0225
4	100.80	68.09	100.8	69.40	22.62	69.34	15.34	100.80	0.0003
5	100.80	68.13	100.8	69.15	23.92	69.43	13.76	100.80	0.0077
6	100.80	71.31	100.8	69.51	27.82	69.27	9.94	123.20	0.0057
7	145.60	68.39	145.6	69.35	28.89	69.35	9.08	145.60	0.0000
8	145.60	69.42	145.6	69.36	28.90	69.35	9.08	151.20	0.0000
9	156.80	67.91	156.8	69.20	30.76	69.51	6.78	173.60	0.0116
10	190.40	67.84	190.4	69.06	32.42	69.72	3.64	190.40	0.0505
11	190.40	68.61	190.4	69.02	32.60	69.88	2.24	196.00	0.0825
12	201.60	68.99	201.6	69.02	32.60	70.02	1.33	235.20	0.1066
13	268.80	69.12	268.8	69.02	32.61	70.20	0.34	268.80	0.1323
14	268.80	70.43	268.8	69.12	34.44	70.15	0.28	274.40	0.0857
15	280.00	70.52	280	69.22	36.26	70.02	0.09	308.00	0.0427
16	336.00	70.11	336	69.27	37.01	69.98	0.08	336.00	0.0234
17	336.00	70.18	336						
18	358.40	69.78	358.4						

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