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Revalidation of potassium requirement for maize (*Zea mays*) in Eastern dry zone of Karnataka

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Abstract
Potassium is an essential nutrient for growth and development of crops, which requires greater attention in order to ensure enhanced crop production and mitigation of biotic and abiotic stress as well as improvement in crop quality. However, the reports indicate potassium is being depleted in Indian soils due to imbalanced applications. The present study was conducted to validate the potassium requirement on collecting around one hundred and fifty-eight (158) soil samples from different agro ecological situations (AES) under Eastern Dry Zone of Karnataka analyzed for available potassium and categorized into five classes such as very low, low, medium, high and very high. The critical limit for available potassium and plant potassium content and ratings for available potassium were determined by conducting pot culture experiment in soils collected from different locations under each category. The results revealed that the critical limit for soil available K was 105 kg K ha^{-1} and 1.72 per cent plant K for maize crop. Based on continuous calibration curve the soil available potassium for Eastern dry zone of Karnataka can be revalidated and categorized as very low, low, medium and high in K recording corresponding to the value of < 105 kg ha^{-1}, 106 to 215 kg ha^{-1}, 216 to 380 kg ha^{-1} and > 380kg ha^{-1} available potassium respectively.

Keywords: Soil available potassium, agro ecological situation, critical limit

Introduction

Potassium is one of the major nutrient elements which will require a greater attention in order to ensure enhanced crop production and mitigation of biotic and abiotic stress as well as improvement in produce quality. Potassium is an essential element for plant growth and is an extremely dynamic ion in plant and soil system. The importance of potassium in the nutrition of crops is very evident. It is involved in large number of physiological processes in plants like osmoregulation, cation-anion balance, protein synthesis and activation of enzymes. It is present comparatively in higher amounts than any other essential plant nutrient in soils (Datta and Mukherjee, 1970) [6]. In Indian soils potassium content varies from less than 0.5 to 3 per cent. Hence, crop responses to application of potassium are often erratic.

Leibig (1840) [9] recognised potassium as one of the major plant nutrients which played a key role in soil fertility and developed potassium mineral fertilizers. Reports support this indicating a negative balance in Indian soils. In Indian soils potassium content varies from less than 0.5 to 3 per cent. Hence, crop responses to application of potassium are often erratic.

However, the reports indicate potassium is being depleted in Indian soils due to imbalanced applications.

Review of past and recent information on K status over five decades showed that there is a gradual decline in K status in Indian soils from high to medium to low status. As a result, wide spread K deficiency in soils and crops has been observed in the recent past. The present study was conducted to validate the potassium requirement for maize with an objective to revalidate the soil fertility ratings for potassium and to assess the critical limit for potassium in maize and to study the status of available potassium in Eastern dry zone of Karnataka.

Materials and Methods

Total one hundred and fifty-eight samples were collected indicating thirty to thirty-five samples as true representative soils to assess the available potassium status of soils of Eastern dry zone (EDZ) of Karnataka which included three districts representing different agro-climatic situations. The details of sample collected is presented in Table - 1. The soil samples collected were air dried, crushed, and passed through a 2-mm sieve before chemical characterization. Soil reaction (1:2.5), Electrical conductivity (EC) and Organic carbon (OC) by Wet oxidation method (Jackson 1973) [11] and available nitrogen (N) was analysed by Micro kjeldahl distillation method (Subbiah and Asija 1956) [18] and Olsen-extractable or Bray's extractable phosphorus (depending on Soil pH) was done by spectroscopy (Jackson 1973) [11]. Further, available potassium was determined by flame photometry and sulphur done by turbidity method (Jackson 1973) [11]. The DTPA extractable micronutrients (Zn, Fe, Mn and Cu) analysis was done using atomic absorption spectroscopy (AAS) (Lindsay and Norwell, 1978) [10].

Pot experiment: to study the critical limits of potassium a pot culture experiment was conducted. Collection of soil sample for pot experiment was done as per above mentioned procedure. Subsequently the soils were categorized into different categories based on available potassium content of soil as detailed below i.e., Low < 141 kg K ha^{-1}, Medium 141 to 336 kg K ha^{-1} and High > 336 kg K ha^{-1} (LMH concept) into four categories, *viz*., very low (<100 kg K ha^{-1}), low (101-200 kg K ha^{-1}), medium (201-300 kg K ha^{-1}) and high (>300 kg K ha^{-1}) potassium (six sets each). Soils samples (24) from twenty-four different locations were selected for pot experiment comprising of nine treatments and replicated thrice. The details of experiment are given below

Table 1: Details of soils sampled

Agro climatic zone - 5			
Agro ecological situations			
AES 1	AES 2	AES 3	AES 4
Red sandy loam	Red loamy soils	Red laterite soil	Irrigated
Low rainfall	Medium rainfall	Medium rainfall	
Taluks (Samples number)			
Gouribidanur (17) Parts of Doddaballapura (19) Parts of Mulbagal	Nelamangala (10) Tumkur (9) Gubbi (10) Parts of Chikkaballapura (15) Parts of Mulbagal (10)	Kolar (10) Hosakote (6) Devanahalli (13) Parts of Chikkaballapura	Scattered in all AES (39)
Total number of soil sample = 158			
Major crops grown			
Finger millet, Maize, Redgram, Vegetables: (Gouribidanur, Mulabagalu, Kolar, Chikkaballapura) Maize, Finger millet, Redgram, Vegetables: (Devanahalli, Parts of Doddaballapura, Hosakote, Nelamangala) Paddy, Finger millet, Redgram: (Gubbi & Tumkur)			

Experiment details

Potassium fertility levels: Four (Very low, low, medium and high)

Number of soils in each category: Six

Treatment details

T_1	Control
T_2	Rec. NP + FYM
T_3	Rec. NP
T_4	Rec. NPK + FYM
T_5	Rec. NPK
T_6	150% K + Rec. NP + FYM
T_7	150% K + Rec. NP
T_8	200% K + Rec. NP + FYM
T_9	200% K + Rec. NP

Crop details

Crop: Maize

Variety: Nityashree (NAH 2049)

Recommended NPK: 100:50:25 kg ha^{-1}

FYM: 7.5 tons ha^{-1}

Design of experiment: CRD

Calculated quantity of fertilizer and FYM was added to soil, based on the weight of soil taken (20 kgs) for each pot as per the treatment details and maize seeds sown. The moisture content of soil in pots was maintained at field capacity. Weed management and plant protection measures were taken up as per package of practice. Soil and plants samples were collected after 30 days of sowing and analyzed. The crop was grown for 60 days and later plants were harvested separately from each pot and dry matter was recorded and post-harvest samples were collected and analysed for different nutrients content *viz*., total N by Kjeldahl digestion distillation method, total P by diacid digestion and vanadomolybdate yellow colour method, total K by diacid digestion and flame photometer method, total Ca & Mg by diacid digestion with versenate titration method, total S by diacid digestion with turbidometry (Piper, 1966) [13].

The critical limit of available potassium was calculated by plotting (Cate and Nelson, 1971) [4] the available potassium on X – axis and relative yield on Y- axis. The FYM treated pots were not taken into consideration to determine critical limit and revalidate soil available potassium

Relative yield = {{1- [(maximum yield – check yield)/check yield]} X 100}

The soils were categorized into very low, low, medium and high by adopting continuous calibration curve developed by Sirappa and Peter, (2007) [15]. The available K and relative yield after the harvest of maize crop were used to derive graph for categorisation of soil K. The samples which recorded relative yield less than 45 per cent were considered to be very low, those which recorded yield between 45 and 60 per cent were categorized low, and between 60 and 75 per cent as medium and samples which recorded yield above 75 per cent were considered as high. The relative yield per cent was considered based on the maximum points recorded in the category as per results by Cope and Rouse, (1973) [5] and Leiwakabessy, (1996) [8].

Results and Discussion

Status of available potassium in Eastern Dry Zone of Karnataka

The available potassium in soils of Eastern dry zone of Karnataka varied from low to medium in range. Out of 158 samples collected 36 belonged to AES-1, 54 to AES-2, 29 to AES-3 and 39 from AES-4 which includes irrigated condition is presented in Table - 2. Among the four ecological situations, AES-4 (irrigated and red soil) recorded higher number of samples under high K status (14 samples) which accounts to 35.90% followed by AES-1(red sandy loam soil) and AES-2 (red loamy soils). The AES-2 recorded higher number of samples which belongs to medium and low category. The data indicates that in most agro-ecological situations the soils recorded low to medium K status except that of AES-4, recorded medium to high status since it comes under irrigated condition, the K status in soil during wetting and drying process leads to movement of K ion from lower layers to surface layers of soil. Majority of the soils belongs to low to medium K status in Eastern dry zone of Karnataka (Zone 5) which is due to continuous cropping without addition of potassium fertilizers and organic manures. About 23.42 per cent (total of four agro-ecological situations) were under high category which soon will degrade to lower category by continuous cropping. Indian soils were said to be rich in potassium minerals but over the time due to intensive cropping the soils are depleting with respect to soil potassium from high K to medium and to low soil potassium category because of dynamic equilibrium which maintains soil solution K. Similarly, Takkar, (1996) [21] opined that very small pockets of places in Karnataka fall under high K status while majority were under low to medium K status and major parts of Kolar, Bangalore and Tumkur have medium K status which belongs to eastern dry zone of Karnataka.

Table 2: Status of available potassium (kg ha^{-1}) in Agro climatic zone – 5 of Karnataka

Place	Av.K (kg ha^{-1})	Place	Av.K (kg ha^{-1})	Place	Av.K (kg ha^{-1})
Basavapura, Gowribidanur, AES1	122.30	Hegunda, Nelamangala AES2	474.43	Malleshwarnagar, Kolar AES3	274.18
Demgattanahalli, Gowribidanur AES1	108.86	Narashipura, Nelamangala AES2	513.41	Vakkaleri, Kolar AES3	373.63
T.Bommasandra, Gowribidanur AES1	249.98	Makenahalli, Nelamanagala AES2	288.96	Chinnapura, Kolar AES3	123.65
Kenkere, Gowribidanur AES1	65.86	Enchenahalli, Nelamangala AES2	166.66	Dandigonahalli, Kolar AES3	327.94
Vedalveni, Gowribidanur AES1	510.72	Manne, Nelamangala AES2	758.02	Beglibeneganahalli, Kolar AES3	104.83
Bandaralahalli, Gowribidanur AES1	302.4	Thyamagondlu, Nelamangala AES2	552.38	Ammerehalli, Kolar AES3	158.59
Benchippanahalli, Gowribidanur AES1	165.31	Kalghatta, Nelamangala AES2	220.42	Beglibeneganahalli, Kolar AES3	37.63
Gidaganahalli, Gowribidanur AES1	227.14	Mallunugallihattu, NelamanagalaAES2	379.01	Mediyalla, Kolar AES3	75.26
Kachamachanahalli, Gowribidanur AES1	563.14	Basavanahalli, Nelamangala AES2	307.78	Veenagal, Kolar AES3	72.58
Alkapura, Gowribidanur AES1	379.01	Mylanahalli, Nelamangala AES2	110.21	Kurugal, Kolar AES3	177.41
Hale upparahalli, Gowribidanur AES1	259.39	Nijagahalli, Tumkur AES2	474.43	Sonnahallipura, Hoskote AES3	161.28
Kotaldinne, Gowribidanur AES1	146.5	Linganahalli, Tumkur AES2	76.61	Jadigenahalli, Hoskote AES3	80.64
Kadaluveri, Gowribidanur AES1	278.21	Dodderi, Tumkur AES2	165.31	Jadigenahalli, Hoskote AES3	88.70
Herebindu, Gowribidanur AES1	313.15	G.G.Palya, Tumkur AES2	133.06	Haraluru, Hoskote AES3	94.08
Sigadigere, Gowribidanur AES1	131.71	Sorekunte, Tumkur AES2	263.42	Haraluru, Hoskote AES3	337.34
Nulugumanahalli, Gowribidanur AES1	153.22	Helenijoglu, Tumkur AES2	327.94	Cheemasandra, Hoskote AES3	220.42
Heggenahalli, Gowribidanur, AES1	182.78	Ballapura, Tumkur AEs2	130.37	Chikkamaralli, Devanahalli AES3	170.69
Huskuru, Doddaballapura AES1	194.88	Byagadralli, Tumkur AES2	88.70	Chikkamaralli, Devanahalli AES3	413.95
Kuntanahalli, Doddaballapura AES1	536.26	Sorekunte, Tumkur AES2	192.19	Chikkamaralli, Devanahalli AES3	604.80
Kamanagrahara, Doddaballapura AES1	71.23	Gubbi AES2	173.38	Settarahalli, Devanahalli AES3	288.96
Saslu, Doddaballapura AES1	333.31	Ammanghatta, Gubbi AES2	77.95	Chikkagollahalli, Devanahalli AES3	379.01
Saslu, Doddaballapura AES1	110.21	Doddagini, Gubbi AES2	189.50	Byadarahalli, Devabahalli AES3	205.63
Thodalabande, Doddaballapura AES1	129.02	Doddagini, Gubbi AES2	153.22	Jalige, Devanahalli AES3	245.95
Kanakenahalli, Doddaballapura AES1	276.86	M.H.Patna Gubbi AES2	452.93	Thindlu, Devanahalli AES3	251.33
Adakavalla, Doddaballapura AES1	185.47	Mattighatta, Gubbi AES2	145.15	Neraganahalli, Devanahalli AES3	286.27
Kadathippuru, Doddaballapura AES1	201.6	Channashettyhalli, Gubbi AES2	225.79	Koramangala, Devanahalli AES3	283.58
Akkathamanahalli, Doddaballapura AES1	275.52	Kundernahalli Gubbi AES2	159.94	Koramangala Devanahalli AES3	243.26
Kattivasahalli, Doddaballapura AES1	223.1	Kundernahalli Gubbi AES2	284.93	Vijaypura, Devanahalli AES3	698.88
Doddabelavangala, Doddaballapura AES1	643.78	Nittur, Gubbi AES2	92.74	Channarayapatna, Devanahalli AES3	282.24
Sonnenahalli, Doddaballapura AES1	799.68	Yerahalli, Chikkaballapura AES2	77.95	Tubgunte, Doddaballapura AES4	40.32
Tubinakere, Doddaballapura AES1	266.11	Suthapete, Chikkaballapura AES2	318.53	Hambalgere, Doddaballapura AES4	134.40
Lakkasandra, Doddaballapura AES1	581.95	Katenahalli, Chikkaballapura AES2	331.97	Neralaghatta, Doddaballapura AES4	147.84
Tubegere, Doddaballapura AES1	353.47	Bichaganahalli, Chikkaballapura AES2	124.99	Purushanahalli, Doddaballapura	102.14
Hadonahalli, Doddaballapura AES1	168.00	Iddolu, Chikkaballapura AES2	288.96	Kamangrahara, Doddaballapura AEs4	551.04
Kanasavadi, Doddaballapura AES1	278.21	Chipaganahalli, Chikkaballapura AES2	114.24	Neralghatta, Doddaballapura AES4	227.14
Honnavara, Doddaballapura AES1	614.21	Chipaganahalli, Chikkaballapura AES2	104.83	Honnapanahalli, Gowribidanur AES4	426.05
Kempaganahalli, Chikkaballapura AES2	108.86	Kuduthi, Chikkaballapura AES2	103.49	Hosur, Gowribidanur, AES4	544.32
Chikathekahalli, Chikkaballapura AES2	137.09	Nandi, Chikkaballapura AES2	381.70	Kanganakoppa, Gowribidanur AES4	118.27
Gandhipura, Chikkaballapura AES2	129.02	Bandamanahalli, Chikkaballapura AEs2	206.98	Henumanthapura, Gowribidanur AES4	244.61
Erenahalli, Chikkaballapura AES2	118.27	Kondavanahalli, Chikkaballapura AES2	240.58	Kalludi, Gowribidanur AES4	72.58
Kurudumalai, Mulabagalu AES2	262.08	Puttarahalli, Mulabagalu AES2	127.68	Nagaragere, Gowribidanur AES4	75.26
Kadaripura, Mulabagalu AES2	174.72	Varadagunahalli, Mulabagalu AES2	201.6	Bugudihalli, Nelamangala AES4	417.98
Mulabagalu, Kolar AES2	77.95	Varadagunahalli, Mulabagalu AES2	107.52	Adivasahalli, Nelamangala AES4	362.88
Kurubarahalli, Mulabagalu AES2	163.97	Gummakal, Mulabagalu AES2	158.59	Mallarabanavadi, Nelamangala AES4	297.02
Puttarahalli, Mulabagalu AES2	137.09	Avani, Mulabagalu AES2	172.03	Tandaga, Tumkur AES4	57.79
Nagarhole, Tumkur AES4	129.02	Ranganahalli, Tumkur, AES4	266.11	Pottavarahalli, Chikkaballapura AES4	129.02
Brahmadevarahalli, Tumkur AES4	124.99	Lakshmipura, Chikkaballapura AES4	61.82	Nangali, Mulabagalu AES4	411.26
Nagarakatte, Tumkur AES4	178.75	Mittemari, Chikkaballapura AES4	122.30	Mudiyanur, Mulabagalu AES4	626.30
Chatrakodihalli, Kolar AES4	169.34	Busunahalli, Kolar AES4	314.50	Theneyur, Hoskote AES4	643.78
Marenahalli, Kolar AES4	533.57	Sulibele, Hoskote AES4	631.68	Nandagudi, Hoskote AES4	407.23
Naganala, Kolar AES4	409.92	Chikkalagere, Hoskote AES4	309.12	Rampura, Hoskote AES4	823.87
Avathi, Devanahalli AES4	185.47	Honnavara, Devanahalli AES4	427.39	Channarayapatna, Devanahalli AES4	206.98
Avathi, Devanahalli AES4	166.66	Channarayapatna, Devanahalli	263.42		

Effect of varied levels of potassium on dry matter yield (g pot^{-1}) of maize in soils of different potassium fertility status

The data pertaining to the dry matter yield (g pot^{-1}) of maize in soils of different potassium fertility are depicted in Table - 3. The data indicates that out of 24 soil samples utilized the Soil (S4) in high K fertility recorded higher dry matter accumulation (171.06, 190.39, 181.17, 246.40, 215.56, 310.68, 291.60, 330.60 and 306.42 g pot^{-1}) as compared to all other soil samples in other different K fertility soils. However, in comparison among the treatments the application of super optimal dose of K (200 per cent K) along with incorporation of FYM to soil and recommended doses of N and P in Soil (S2) recorded higher dry matter (335.34 g pot^{-1}) when comparison to all other treatments indicating the maize responded to higher dose of K application than recommended dose even in presence of high available K as evidence to that of luxury consumption. Similar observations have been recorded by Singh and Pathak, (2002) [14] and Lavanya *et al.* (2010) [7] indicating increased yield with increasing doses of potassium application.

Changes in chemical properties of soil in the experiment

The data pertaining to changes in soil pH, available nitrogen, phosphorus and potassium content in soil after harvest of maize (60 DAS) in presented in table 4 to 7.

The data in the Table-4 indicates that irrespective of the soil K fertility the lowest soil pH was recorded in treatment T3 where in only recommended N and P was applied which was lower than the control (T1) too. The soil pH ranged from 4.18 to 7.38 with the treatments and among the treatments. However, the S3 in High K fertility recorded higher soil pH (7.38, 7.17, 7.16, 7.24, 7.18, 7.24, 7.24, 7.30 and 7.27 in T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8 and T_9 respectively). The treatmental effect on soil pH was found to be obvious in experiment with application of FYM which has a buffering effect in soil (Basumantary and Talukdar (1998) [2] and Srikanth *et al.* (2000) [16] as compared to fertilizers alone.

There was no significant relationship recorded with respect to available nitrogen and varied K fertility soils (Table 5). Whereas the difference in treatment with application of FYM in combination with recommended fertilizers and that of fertilizers alone was positive indicating the relationship of available nitrogen to that of organic matter content in soil. The results were corroborative to that of Suresh *et al.*, (1999) [20] and Bandyopadhyay and Puste, (2002) [1] who pointed out that addition of FYM improved available nitrogen which would be ascribed to the mineralization of N from FYM. However, among all the soil in different K

Table 3: Effect of varied levels of potassium on dry matter yield (g pot^{-1}) of maize after the harvest (60 DAS) in soils of different potassium fertility status

Treatments	Dry matter yield (g pot^{-1}) in very low K fertility							Dry matter yield (g pot^{-1}) in low K fertility						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
T_1	90.50	84.45	73.65	68.26	79.65	80.25	79.46	119.98	125.86	135.68	115.39	119.30	135.33	125.26
T_2	120.05	124.91	130.46	99.36	110.33	125.36	118.41	151.77	152.44	160.99	165.31	142.98	170.14	157.27
T_3	105.32	110.35	86.21	74.53	89.88	91.70	93.00	130.26	135.15	139.63	140.27	126.63	150.31	137.04
T_4	201.60	198.31	189.39	150.29	156.21	164.22	176.67	210.54	230.48	220.25	210.34	182.57	225.33	213.25
T_5	164.65	140.42	134.42	115.33	131.31	131.16	136.22	189.22	189.14	185.64	180.21	156.93	189.55	181.78
T_6	230.48	221.32	261.38	210.53	209.59	216.31	224.94	275.54	284.23	280.37	281.53	234.44	250.38	267.75
T_7	180.84	164.58	188.91	164.56	189.26	196.22	180.73	215.24	212.50	220.46	210.71	190.05	210.57	209.92
T_8	294.43	286.31	294.23	256.23	275.54	285.34	282.01	308.54	310.58	325.31	300.27	280.57	285.92	301.86
T_9	200.01	219.52	201.22	201.32	192.56	186.24	200.15	256.32	275.25	290.15	274.85	212.46	240.22	258.21
Mean	176.43	172.24	173.32	148.93	159.37	164.09		206.38	212.85	217.61	208.76	182.88	206.42	
S.Em±	0.058	0.101	0.128	0.217	0.122	0.101		0.103	0.475	0.416	0.071	0.563	0.124	
CD (p=0.05)	0.174	0.303	0.383	0.650	0.367	0.302		0.308	1.425	1.248	0.212	1.688	0.373	

Treatments	Dry matter yield (g pot^{-1}) in medium K fertility							Dry matter yield (g pot^{-1}) in high K fertility						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
T_1	115.71	125.22	140.25	130.30	145.22	160.38	136.18	138.25	141.29	150.37	171.06	157.23	156.29	152.41
T_2	186.29	189.32	168.17	190.39	185.38	185.45	184.16	175.61	185.29	191.19	190.39	186.36	190.50	186.56
T_3	141.51	150.22	150.42	145.37	161.47	156.22	150.87	148.64	159.88	175.44	181.17	168.75	174.22	168.02
T_4	260.23	234.10	219.49	254.36	250.58	244.54	243.88	270.33	260.37	230.36	246.40	245.38	256.29	251.52
T_5	198.36	196.22	187.30	203.56	196.46	199.28	196.86	195.54	203.25	195.72	215.56	201.35	206.54	202.99
T_6	304.45	271.31	264.30	298.17	291.54	296.50	287.71	310.76	291.48	272.54	310.68	302.34	284.42	295.37
T_7	265.33	230.20	220.31	250.29	245.23	220.36	238.62	255.37	268.39	231.54	291.60	280.51	265.44	265.48
T_8	325.44	309.46	300.04	330.38	315.57	316.37	316.21	327.68	335.34	319.50	330.60	325.55	310.51	324.86
T_9	295.89	286.36	285.24	291.19	296.67	280.66	289.34	298.44	298.67	266.49	306.42	295.46	286.54	292.00
Mean	232.58	221.38	215.06	232.67	232.01	228.86		235.62	238.22	225.91	249.32	240.33	236.75	
S.Em±	0.165	0.061	0.082	0.097	0.104	0.153		0.101	0.204	0.166	0.129	0.140	0.086	
CD (p=0.05)	0.495	0.183	0.246	0.292	0.311	0.458		0.303	0.611	0.497	0.388	0.419	0.258	

*T_1: Control, T_2: 100% NP + FYM, T_3: 100% NP, T_4:100% NPK + FYM, T_5: 100% NPK, T_6: 150% K + Rec. NP + FYM, T_7: 150% K + Rec. NP, T_8: 200% K + Rec. NP + FYM, T_9: 200% K + Rec. NP, S1:Soil 1, S2:Soil 2, S3:Soil 3, S4:Soil 4, S5:Soil 5, S6:Soil 6

Table 4: Effect of varied levels of potassium on soil pH after the maize harvest (60 DAS) in soils of different potassium fertility status

Treatments	Soil pH in very low K fertility							Soil pH in low K fertility						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
T_1	6.72	6.30	5.39	5.99	5.17	4.46	5.67	6.74	5.12	6.14	5.53	5.72	5.52	5.79
T_2	6.33	6.15	5.15	5.81	4.99	4.23	5.44	6.52	4.94	5.82	5.41	5.56	5.38	5.61
T_3	6.24	6.12	5.09	5.75	4.95	4.18	5.39	6.47	4.90	5.76	5.35	5.53	5.32	5.56
T_4	6.36	6.24	5.23	5.84	5.06	4.32	5.51	6.57	5.04	5.86	5.49	5.64	5.42	5.67
T_5	6.33	6.23	5.21	5.79	4.96	4.26	5.46	6.55	4.95	5.79	5.40	5.58	5.37	5.61
T_6	6.48	6.27	5.31	5.86	5.11	4.37	5.57	6.60	5.07	5.92	5.52	5.66	5.47	5.71
T_7	6.47	6.26	5.27	5.81	5.07	4.34	5.54	6.58	4.98	5.86	5.49	5.62	5.40	5.66
T_8	6.66	6.29	5.34	5.90	5.12	4.44	5.63	6.66	5.05	5.96	5.51	5.70	5.51	5.73
T_9	6.55	6.25	5.30	5.84	5.10	4.34	5.56	6.60	5.08	5.83	5.51	5.68	5.45	5.69
Mean	6.46	6.24	5.25	5.84	5.10	4.33		6.59	5.02	5.88	5.47	5.63	5.43	
S.Em±	6.97	6.54	5.68	6.25	5.48	4.53		6.87	5.24	6.12	5.68	5.89	5.65	
CD (p=0.05)	0.012	0.007	0.007	0.010	0.014	0.018		0.009	0.012	0.009	0.016	0.014	0.015	

Treatments	Soil pH in medium K fertility							Soil pH in high K fertility						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
T_1	5.24	5.54	5.13	6.08	6.31	5.35	5.61	7.24	6.75	7.38	7.01	6.36	6.50	6.86
T_2	5.11	5.38	4.86	5.86	6.16	5.25	5.44	6.96	6.55	7.17	6.82	6.18	6.35	6.67
T_3	5.07	5.35	4.81	5.79	6.15	5.17	5.39	6.91	6.49	7.16	6.74	6.14	6.26	6.62
T_4	5.16	5.46	4.92	5.86	6.21	5.26	5.48	7.06	6.58	7.24	6.86	6.26	6.42	6.74
T_5	5.11	5.42	4.88	5.84	6.25	5.21	5.45	6.96	6.56	7.18	6.78	6.17	6.35	6.67
T_6	5.19	5.49	4.96	5.94	6.26	5.28	5.52	7.12	6.67	7.24	6.91	6.25	6.45	6.77
T_7	5.14	5.46	4.94	5.86	6.25	5.27	5.49	7.09	6.58	7.24	6.86	6.24	6.43	6.74
T_8	5.22	5.54	4.96	5.96	6.28	5.27	5.54	7.17	6.69	7.30	6.96	6.28	6.48	6.81
T_9	5.19	5.48	4.97	5.92	6.27	5.26	5.52	7.15	6.62	7.27	6.94	6.27	6.44	6.78
Mean	5.16	5.46	4.94	5.90	6.24	5.26		7.07	6.61	7.23	6.88	6.24	6.41	
S.Em±	5.36	5.68	5.12	6.23	6.43	5.43		7.30	6.86	7.40	7.19	6.52	6.64	
CD (p=0.05)	0.016	0.019	0.016	0.015	0.017	0.015		0.015	0.016	0.015	0.012	0.015	0.014	

*T_1: Control, T_2: 100% NP + FYM, T_3: 100% NP, T_4:100% NPK + FYM, T_5: 100% NPK, T_6: 150% K + Rec. NP + FYM, T_7: 150% K + Rec. NP, T_8: 200% K + Rec. NP + FYM, T_9: 200% K + Rec. NP, S1:Soil 1, S2:Soil 2, S3:Soil 3, S4:Soil 4, S5:Soil 5, S6:Soil 6

Table 5: Effect of varied levels of potassium on available nitrogen (kg ha^{-1}) after the maize harvest (60 DAS) in soils of different potassium fertility status

Treatments	Av. N (kg ha^{-1}) in very low K fertility							Av. N (kg ha^{-1}) in low K fertility						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
T_1	253.26	223.32	224.56	216.39	209.47	425.47	258.74	238.27	183.55	231.39	185.26	268.35	454.46	260.21
T_2	265.28	235.36	239.41	230.61	230.57	450.66	275.32	252.56	201.51	253.17	206.40	289.40	478.29	280.22
T_3	258.25	228.41	234.38	221.52	218.49	439.68	266.79	243.24	184.41	245.50	191.34	273.29	465.28	267.18
T_4	278.33	256.31	256.28	246.43	251.48	458.52	291.23	272.51	231.55	268.45	228.29	306.44	490.57	299.63
T_5	268.45	241.40	242.32	238.32	239.55	445.57	279.27	265.20	218.49	256.49	218.46	292.23	476.13	287.83
T_6	279.33	257.56	257.41	247.29	253.56	448.51	290.61	273.26	232.47	268.45	230.66	307.29	492.55	300.78
T_7	268.39	242.33	243.49	237.17	240.45	446.57	279.73	266.32	219.49	256.31	219.37	293.41	477.51	288.73
T_8	280.42	257.66	256.30	248.45	253.98	449.43	291.04	273.87	232.89	269.44	230.82	307.65	492.60	301.21
T_9	268.38	243.29	243.64	237.60	240.53	447.17	280.10	266.46	219.52	256.27	219.55	294.35	478.87	289.17
Mean	268.89	242.84	244.20	235.97	237.56	445.73		261.30	213.76	256.16	214.46	292.49	478.47	
S.Em±	276.30	250.40	250.40	219.26	231.80	463.68		261.20	206.98	254.00	208.80	292.32	580.65	
CD (p=0.05)	0.11	0.12	0.13	0.13	0.10	0.11		0.10	0.11	0.14	0.13	0.14	0.11	

Treatments	Av. N (kg ha^{-1}) in medium K fertility							Av. N (kg ha^{-1}) in high K fertility						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
T_1	224.22	394.57	312.64	245.57	225.22	215.43	269.61	210.68	386.21	238.37	395.37	224.56	285.28	290.08
T_2	238.26	408.49	335.45	268.57	249.55	230.60	288.49	228.64	403.56	255.31	412.77	238.54	307.31	307.69
T_3	224.38	398.22	320.52	256.50	239.56	222.51	276.94	215.44	394.47	241.36	406.39	229.39	292.57	296.60
T_4	261.21	436.19	358.34	285.45	272.38	257.39	311.83	255.40	426.41	278.36	435.38	259.43	326.59	330.26
T_5	245.45	418.32	346.47	272.33	256.55	245.73	297.47	241.38	418.42	256.30	426.43	245.40	318.42	317.73
T_6	262.50	437.34	359.45	286.37	273.36	258.31	312.89	256.70	427.55	279.43	436.37	260.48	327.42	331.33
T_7	246.52	419.41	346.71	273.49	257.47	246.44	298.34	242.38	419.46	257.49	426.32	246.47	319.46	318.60
T_8	263.36	437.56	359.70	286.48	273.85	258.80	313.29	256.88	427.80	279.63	436.58	260.65	327.66	331.53
T_9	246.89	419.85	346.87	273.83	257.89	246.85	298.70	242.80	419.83	257.84	427.22	246.79	319.84	319.05
Mean	245.86	418.88	342.91	272.07	256.20	242.45		238.92	413.75	260.45	422.54	245.75	313.84	
S.Em±	246.11	437.42	337.68	266.00	248.16	238.35		221.60	430.30	261.65	418.2	243.84	302.40	
CD (p=0.05)	0.127	0.406	0.151	0.119	0.124	0.099		0.10	0.39	0.13	0.13	0.08	1.10	

*T_1: Control, T_2: 100% NP + FYM, T_3: 100% NP, T_4:100% NPK + FYM, T_5: 100% NPK, T_6: 150% K + Rec. NP + FYM, T_7: 150% K + Rec. NP, T_8: 200% K + Rec. NP + FYM, T_9: 200% K + Rec. NP, S1:Soil 1, S2:Soil 2, S3:Soil 3, S4:Soil 4, S5:Soil 5, S6:Soil 6

Fertility soils, the Soil S6 in low K fertility recorded higher available nitrogen (454.46, 478.29, 465.28, 490.57, 476.13, 492.55, 477.51, 492.60, 478.87 kg ha^{-1} in T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8 and T_9 respectively)

Similar trend was recorded with respect to available phosphorus (Table 6) as that of nitrogen, it did not with the increase in soil K fertility. However, the available phosphorus content recorded higher in treatments which received FYM along with NPK as incorporation of FYM in combination with inorganic fertilizers improved the available P status of the soil which is attributed to enhanced solubilisation of native P in soil and addition of P through FYM and use of phosphate fertilizers (Suresh *et al*, 1999). The soil S3 in medium K fertility recorded higher available phosphorus (48.34, 54.60, 51.36, 58.33, 54.33, 59.25, 55.32, 59.51, 55.90 kg ha^{-1} in T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8 and T_9 respectively).

The interaction between levels of potassium application and different potassium fertility soils was significant as represented in Table -7. Treatment T_8 (200% K + rec. NP + FYM) recorded significantly higher available potassium in soils and with respect to increase in soil K fertility as the results were corroborative to that of Muneshwar Singh and Wanjari, (2012) [12] who observed an increased response of crops to the application of potassium and absence of K resulted in decline of available K. The decline was ceased with addition of K, suggesting the need to modify K limits for rating soils and accordingly K recommendation to be done. Further, the Soil S4 in High K fertility recorded higher available potassium (619.44, 626.37, 620.45, 640.34, 629.19, 649.33, 634.29, 661.45, 652.45 kg ha^{-1} in T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8 and T_9 respectively).

Critical limits of soil and plant potassium for maize in Eastern dry zone of Karnataka

Critical limits are said to be those values of soil and plant potassium values below which the response of crop for increased yield to the added nutrient. The data collected on soil available nutrient status and dry matter yield from the experiment indicates the critical level for K in the soil (Below which the yield reduces) and was calculated based on Cate and Nelson (1971) [4] graphical method. The critical limit for soil available K can be derived as 105.00 kg ha^{-1} and critical limit of plant K for maize as 1.72 per cent as indicated in Fig-1. Similar findings were recorded by Srinivasa Rao and Takkar, (1997) [17] and Bedi *et al*. (2002) [3] who reported critical limit of soil K was 82 mg kg^{-1} when graded doses of K (0, 6, 12 and 18 mg kg^{-1}) were applied in low, medium and high K soils and plant K was 1.8 per cent at which crop yield would be optimum.

Table 6: Effect of varied levels of potassium on available phosphorus (kg ha^{-1}) after the maize harvest (60 DAS) in soils of different potassium fertility status

Treatments	Av. P_2O_5 (kg ha^{-1}) in very low K fertility							Av. P_2O_5 (kg ha^{-1}) in low K fertility						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
T_1	15.33	20.35	15.54	41.41	14.67	18.50	20.97	24.57	17.36	46.22	44.24	48.45	16.43	32.87
T_2	32.28	35.38	29.65	48.34	31.31	34.62	35.26	38.49	29.25	54.48	49.27	54.53	28.60	42.44
T_3	28.41	29.59	24.61	42.37	22.46	25.49	28.82	32.40	24.49	48.33	42.45	50.49	23.42	36.93
T_4	36.43	39.33	38.36	54.53	37.50	42.48	41.44	44.64	34.28	58.36	54.58	58.71	34.19	47.46
T_5	31.55	34.63	31.62	49.29	32.30	35.45	35.81	37.55	28.36	52.35	51.29	52.38	29.39	41.89
T_6	37.51	39.65	38.61	55.48	37.34	43.41	42.00	45.78	35.16	58.20	55.51	58.54	35.22	48.07
T_7	32.46	35.38	34.68	48.51	34.45	37.37	37.14	37.33	29.65	53.23	52.59	51.53	30.40	42.46
T_8	38.26	40.57	39.58	55.62	38.43	44.64	42.85	46.40	35.44	58.39	56.05	59.24	36.41	48.66
T_9	33.60	35.25	35.16	47.30	33.65	37.80	37.13	37.30	30.43	54.29	53.32	52.40	30.83	43.09
Mean	30.87	33.57	31.98	48.32	31.46	35.53		38.27	29.38	53.76	51.03	54.03	29.43	
S.Em±	17.57	24.63	19.54	46.36	17.47	22.76		29.32	21.42	52.40	52.18	54.82	20.54	
CD (p=0.05)	0.11	0.12	0.10	0.10	0.14	0.10		0.13	0.08	0.09	0.10	0.14	0.10	

Treatments	Av. P_2O_5 (kg ha^{-1}) in medium K fertility							Av. P_2O_5 (kg ha^{-1}) in high K fertility						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
T_1	22.50	45.50	48.34	34.51	18.62	36.45	34.32	21.52	29.52	19.68	30.74	29.52	21.37	25.39
T_2	31.62	52.28	54.60	46.62	34.36	44.60	44.01	29.42	36.27	35.38	37.41	41.42	34.30	35.70
T_3	27.56	48.37	51.36	41.60	28.34	41.32	39.76	24.45	31.38	28.43	32.39	32.47	26.37	29.25
T_4	37.33	56.13	58.33	52.51	40.22	49.56	49.01	36.29	39.52	39.41	44.19	49.38	41.33	41.69
T_5	34.50	48.53	54.33	48.48	36.35	46.50	44.78	29.40	35.29	34.40	37.64	42.55	33.33	35.44
T_6	38.36	56.51	59.25	52.61	40.51	50.24	49.58	37.17	40.50	40.44	45.23	50.29	42.25	42.65
T_7	35.38	49.41	55.32	49.29	37.51	47.34	45.71	30.55	36.26	34.65	38.28	43.38	33.40	36.09
T_8	38.39	57.49	59.51	52.88	41.25	50.64	50.03	37.35	40.61	40.64	45.24	50.37	43.37	42.93
T_9	35.41	49.60	55.90	49.53	37.86	47.43	45.96	30.84	36.34	35.56	38.32	43.50	34.25	36.47
Mean	33.45	51.54	55.22	47.56	35.01	46.01		30.78	36.19	34.29	38.83	42.54	34.44	
S.Em±	26.73	58.90	84.81	37.36	24.61	43.51		25.94	33.14	23.95	31.20	33.40	26.15	
CD (p=0.05)	0.098	0.124	0.383	0.120	0.089	0.096		0.16	0.42	0.12	0.11	0.11	0.11	

*T_1: Control, T_2: 100% NP + FYM, T_3: 100% NP, T_4:100% NPK + FYM, T_5: 100% NPK, T_6: 150% K + Rec. NP + FYM, T_7: 150% K + Rec. NP, T_8: 200% K + Rec. NP + FYM, T_9: 200% K + Rec. NP, S1:Soil 1, S2:Soil 2, S3:Soil 3, S4:Soil 4, S5:Soil 5, S6:Soil 6

Table 7: Effect of varied levels of potassium on available potassium (kg ha^{-1}) after the maize harvest (60 DAS) in soils of different potassium fertility status

Treatments	Av. K_2O (kg ha^{-1}) in very low K fertility							Av. K_2O (kg ha^{-1}) in low K fertility						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
T_1	66.83	72.53	68.09	45.48	58.32	58.24	61.58	104.36	103.54	110.82	118.72	100.01	121.74	109.87
T_2	98.47	108.58	96.20	89.67	99.47	101.56	98.99	112.42	115.27	131.58	126.83	129.22	129.41	124.12
T_3	92.27	101.58	89.28	64.74	85.63	83.48	86.16	108.24	109.09	126.65	121.15	123.54	124.83	118.92
T_4	120.23	124.33	116.21	98.56	112.54	121.43	115.55	131.45	132.53	135.43	134.80	136.61	142.34	135.53
T_5	116.57	115.46	109.52	84.54	98.79	102.24	104.52	125.57	126.57	130.49	129.50	126.76	136.35	129.21
T_6	135.43	138.56	127.34	112.38	126.67	138.63	129.84	142.52	143.80	143.56	146.80	142.30	145.26	144.04
T_7	122.58	126.24	122.28	99.57	118.52	125.55	119.12	138.42	134.75	137.60	135.93	138.57	139.26	137.42
T_8	141.32	143.31	135.43	122.49	139.25	145.42	137.87	146.81	151.84	150.71	152.65	158.71	152.66	152.23
T_9	127.56	133.32	121.75	116.36	125.20	132.63	126.14	140.23	145.69	147.61	140.69	151.48	144.52	145.04
Mean	113.47	118.21	109.57	92.64	107.16	112.13		127.78	129.23	134.94	134.12	134.13	137.38	
S.Em±	86.40	85.45	80.20	58.80	75.40	66.54		184.60	133.46	142.98	148.61	129.02	170.69	
CD (p=0.05)	0.12	0.12	0.07	0.13	0.12	0.10		0.10	0.13	0.13	0.09	0.14	0.14	

Treatments	Av. K_2O (kg ha^{-1}) in medium K fertility							Av. K_2O (kg ha^{-1}) in high K fertility						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
T_1	211.00	220.15	173.57	184.54	186.32	163.12	189.79	426.17	401.24	384.32	619.44	364.30	345.38	423.48
T_2	226.31	229.75	178.41	192.65	198.62	180.20	200.99	431.20	415.51	392.53	626.37	375.30	357.65	433.10
T_3	218.70	220.64	175.54	189.49	189.41	169.44	193.87	429.40	410.20	389.20	620.45	369.52	349.40	428.03
T_4	245.75	248.36	194.63	226.51	225.45	198.33	223.17	452.47	429.30	414.33	640.34	391.43	371.46	449.89
T_5	231.53	237.43	185.29	219.71	218.43	186.28	213.11	439.46	421.16	401.39	629.19	384.42	365.23	440.14
T_6	258.58	262.42	211.53	242.59	246.58	212.44	239.02	465.60	442.39	432.31	649.33	412.27	379.59	463.58
T_7	242.53	255.58	198.44	229.34	235.33	205.65	227.81	458.44	430.36	425.46	634.29	398.34	368.42	452.55
T_8	269.63	281.57	226.61	255.61	253.48	230.57	252.91	472.26	451.45	439.33	661.45	420.31	394.58	473.23
T_9	256.66	268.52	219.54	245.58	243.44	219.48	242.20	469.30	448.43	435.23	652.45	406.41	388.34	466.69
Mean	240.08	247.16	195.95	220.67	221.90	196.17		449.37	427.78	412.68	637.04	391.37	368.89	
S.Em±	253.00	256.70	211.60	240.60	241.07	234.50		456.00	426.00	401.46	443.78	383.64	362.88	
CD (p=0.05)	0.14	0.13	0.09	0.12	0.14	0.12		0.098	0.086	0.096	0.112	0.092	0.094	

*T_1: Control, T_2: 100% NP + FYM, T_3: 100% NP, T_4:100% NPK + FYM, T_5: 100% NPK, T_6: 150% K + Rec. NP + FYM, T_7: 150% K + Rec. NP, T_8: 200% K + Rec. NP + FYM, T_9: 200% K + Rec. NP, S1:Soil 1, S2:Soil 2, S3:Soil 3, S4:Soil 4, S5:Soil 5, S6:Soil 6

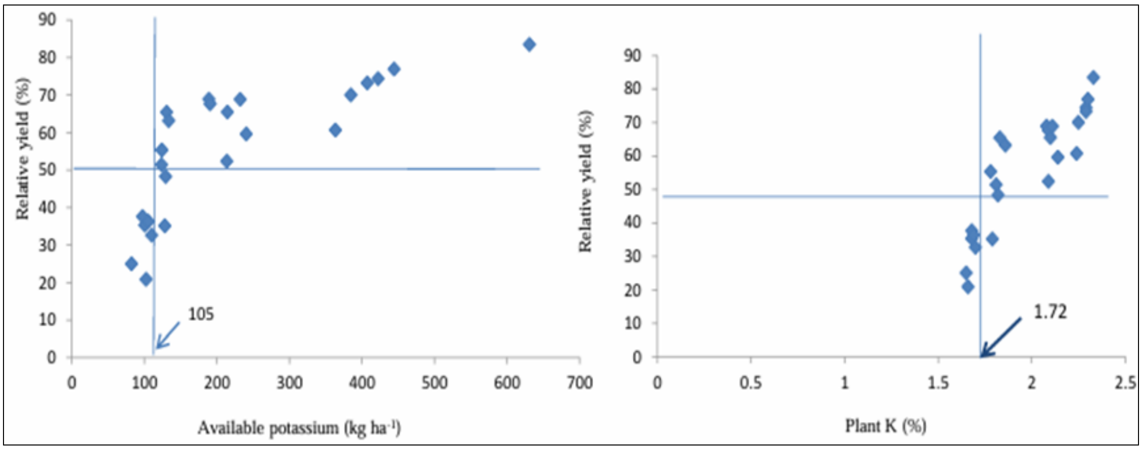

Fig 1: Critical level for available soil K (kg ha^{-1}) and plant K content (%) for maize

Revalidation of soil fertility ratings for potassium in Alfisol

Based on the soil K test values under very low (VL), low (L), medium (M) and high (H) K soils the upper and lower values for each category were worked out using the continuous calibration curve as proposed by Sirappa and Peter, (2007) [15]. The available potassium and relative yield (Per cent) was used to derive graph for categorization of soil K by following the method adopted by Cope and Rouse, (1973) [5] and Leiwakabessy, (1996) [8]. The relative yield refers to the yield achieved on the unfertilized soil relative to the maximum yield achieved on the soils fertilized with potassium. The lower third (45 per cent relative yield) of the response zone was arbitrarily called the very low category. The zone (45 to 60 per cent relative yield) was called as low, the medium zone (60 to 75 per cent relative yield) was called as medium and the high zone more than 75 per cent relative yield was called as high in available potassium (Sirappa and Peter, 2007) [15]. Wide variation in very low, low, medium and high categories of available K may be attributed to the type and nature of the soil and management practices.

Hence, based on results available potassium in soil can be revalidated into very low, low, medium and high category as in Fig -2, the soils with < 105 kg ha^{-1}, 106 to 215 kg ha^{-1}, 216 to 380 kg ha^{-1} and > 380 kg ha^{-1} as very low, low, medium and high respectively in soil available potassium. Similar findings were reported by Sun *et al*. (2009) [19] who opined the fertilizer recommended rates were simulated by models of three factor for 3414 field experiments and fertilizer recommendation index were calculated.

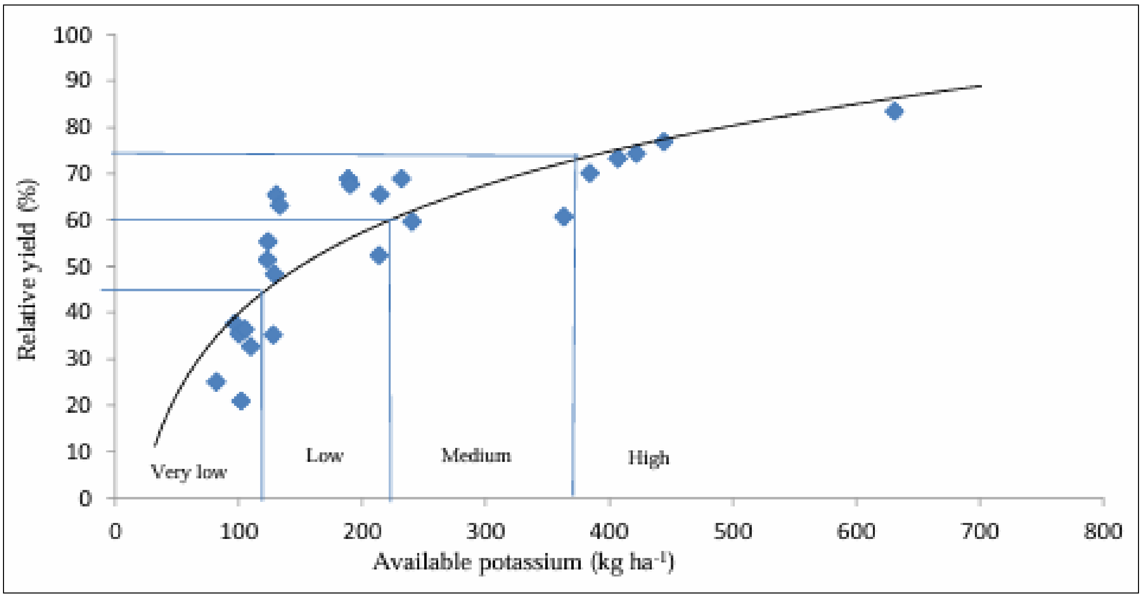

Fig 2: Categorization of soil available potassium (kg ha^{-1})

Conclusion

The results from the study indicates that there is need to apply potassium in both combination of inorganic and organic source as farmers do not apply potassic fertilizers and native soil potassium is depleting with time. The crop response to application of 150 and 200 per cent potassium is greater indicating hunger for potassium.

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