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Research Article

DEVELOPMENT OF FUZZY INFERENCE SYSTEM FOR POTASSIUM REQUIREMENT IN GRAPE GARDEN

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ABSTRACT

The grape is one of the major important fruit crops of the Maharashtra. The high input used crop gives more profit through export as foreign exchange. However, at present, the input in the form of fertilizer for e.g. Potassium, requirement is increasing, so cost also increases. Doses of Potassium are decided by the experts after soil testing. In the present study, the soil samples are collected from different vineyards of the Maharashtra and Karnataka State. In this paper to decide the actual requirement of Potassium, the Fuzzy Information System (FIS) is developed. The laboratory data obtained from the analysis of soil testing report is used as an input to FIS and output results are compared with the results suggested by the expert. It is found that the Potassium requirement suggested by FIS of any grape vineyard is less than the laboratory expert suggestions. Results help to reduce the cost of production without affecting the yield level of the grape vineyard and to maintain the soil quality. Development of Fuzzy Inference System is based on MATLAB Simulation GUI Tool.

INTRODUCTION

Grape is one of the major important fruit crops of the country grown on an area of about 1.19 lakh hectares with an annual production of 25.85 lakh metric tons (National Horticulture Database, India, 2015). In Maharashtra, it is grown on an area of 90,000 hectares with production of 21.60 lakh metric tons (National Horticulture Database, India, 2015). Under the tropical condition, the vine is pruned twice in a year i.e., once after the harvest of fruits during April (back pruning) and again for fruits during October (forward pruning) [4, 7]. During each pruning, the nutrient requirement for soil is different and it varies from grape variety to variety. Potassium is one of the major nutrients supplied to the vineyard for cane maturity and fixation of bunch developed in the bud during fruit bud differentiation stage [15].

Potassium (K) helps in increasing the sugar content in berries. The increase in sugar content ultimately leads to increase in yield per vine [4]. The sweet berries containing high amount of sugar in the form of total soluble solids are generally preferred by the consumers. This is achieved by application of potassium. The main growth stages at which Potassium is needed at optimum for March/April pruning are bud fixing stage, cane maturity stage and period before fruit pruning. Adequate status of Potassium has been emphasised for formation of fruitful buds at bud initiation and differentiation stages [1] and at bud fixation after differentiation (50 to 55 days after pruning) and at cane maturity [19]. After October pruning, adequate Potassium is needed for translocation of sugars to the berries.

The nutrient requirement of grapevine is assessed by the researcher. This is based on the soil test report. It has been noted that the suggestions for requirement of the nutrients from the same vineyard may vary from laboratory to laboratory. The nutrient requirement of each vineyard is different and is based on the nutrient status of each garden. The method used for analyzing the nutrient in a given sample varies from laboratory to laboratory. This shows that vagueness is present in nutrient suggestion. There is also vagueness in the interpretation of the test results. To avoid this we have developed FIS for suggestion of Potassium requirement. The principal contribution of fuzzy logic- is its high power of precision [11]. Most of the practical applications of fuzzy logic are associated with its relational facet. Considering this, Fuzzy Inference System (FIS) suggests the Potassium requirement of grape vineyard based on the soil testing report. The objective of this paper is to avoid the vagueness in Potassium treatment to soil and generate more yields.

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Laboratory Data Base

The Soil is collected from the fields of Solapur, Sangli, Nasik, Pune districts of Maharashtra and Belgaon, Bijapur, Gulbarga districts of Karnataka. The soil samples are testedfrom laboratory of Maharashtra Rajya Draksh Bagaitdar Sangh, Manjri Farm, Pune (Maharashtra) during the season (2013-14 and 2014-15).Total 600samples of different grape vineyards are collected. Samples are collected from the different vineyard. Soil samples are given in table 1.

Table1 Potassium in soil (ppm)

Farmer No.	K	Farmer No.	K	Farmer No.	K	Farmer No.	K	Farmer No.	K
1	3200	41	570	81	910	121	380	161	210
2	1740	42	950	82	1660	122	520	162	300
3	3400	43	710	83	1360	123	840	163	380
4	1000	44	670	84	1540	124	50	164	240
5	1220	45	170	85	1340	125	70	165	250
6	1240	46	510	86	1960	126	230	166	210
7	1300	47	310	87	1120	127	680	167	170
8	1880	48	270	88	1440	128	240	168	200
9	360	49	240	89	1360	129	370	169	230
10	570	50	255	90	1640	130	180	170	250
11	370	51	235	91	900	131	110	171	290
12	420	52	200	92	1460	132	280	172	430
13	270	53	240	93	1520	133	180	173	120
14	650	54	1433	94	1620	134	390	174	290
15	460	55	710	95	1480	135	270	175	460
16	440	56	707	96	1260	136	120	176	80
17	80	57	430	97	3200	137	210	177	120
18	1860	58	570	98	4200	138	120	178	380
19	1540	59	890	99	1060	139	250	179	410
20	1660	60	330	100	1080	140	180	180	350
21	860	61	430	101	660	141	280	181	370
22	1000	62	80	102	2600	142	210	182	370
23	890	63	920	103	2200	143	670	183	320
24	660	64	820	104	790	144	840	184	360
25	750	65	840	105	600	145	220	185	270
26	740	66	400	106	700	146	145	186	270
27	760	67	500	107	540	147	560	187	285
28	1080	68	160	108	640	148	440	188	630
29	720	69	170	109	680	149	260	189	80
30	440	70	810	110	500	150	340	190	950
31	870	71	180	111	490	151	600	191	135
32	760	72	660	112	230	152	680	192	115
33	200	73	200	113	650	153	180	193	660
34	360	74	440	114	810	154	890	194	550
35	480	75	740	115	820	155	495	195	960
36	910	76	850	116	730	156	260	196	1300
37	450	77	1400	117	960	157	180	197	460
38	3200	78	640	118	840	158	160	198	620
39	1740	79	660	119	680	159	283	199	220
40	3400	80	970	120	620	160	1750	200	530

Database: This database is selected randomly from the different farmer's soil. It is given in table 2.

Fuzzy Inference System Developed

For Fuzzy Inference System[8,13,16,18] is developed by using triangular membership functions for input and output variables is shown in fig.1.For Defuzzification,Centroid method is used.The system results are carried out by using MATLAB Software GUI tool[10] shown in fig.2.

Farmer No.	K	Farmer No.	K	Farmer No.	K	Farmer No.	K	Farmer No.	K
201	810	241	360	281	170	321	710	361	970
202	260	242	420	282	230	322	707	362	910
203	670	243	310	283	510	323	430	363	410
204	360	244	460	284	320	324	570	364	490
205	390	245	440	285	280	325	890	365	440
206	1040	246	80	286	490	326	330	366	420
207	650	247	1860	287	220	327	325	367	560
208	400	248	1540	288	170	328	330	368	430
209	420	249	1660	289	260	329	550	369	440
210	270	250	860	290	390	330	430	370	1660
211	520	251	1420	291	409	331	80	371	1360
212	1420	252	1000	292	310	332	920	372	1540
213	1740	253	890	293	270	333	820	373	1340
214	1080	254	660	294	240	334	840	374	1960
215	370	255	750	295	200	335	400	375	1120
216	340	256	740	296	234	336	500	376	1440
217	340	257	760	297	255	337	160	377	1360
218	430	258	1080	298	235	338	170	378	1640
219	570	259	720	299	200	339	810	379	900
220	480	260	440	300	240	340	180	380	1460
221	170	261	870	301	1433	341	660	381	1520
222	360	262	760	302	580	342	200	382	1620
223	860	263	200	303	410	343	440	383	1480
224	880	264	360	304	460	344	740	384	1260
225	560	265	480	305	455	345	1580	385	3200
226	310	266	250	306	440	346	230	386	4200
227	3200	267	170	307	470	347	340	387	1060
228	1740	268	110	308	410	348	200	388	1080
229	3400	269	170	309	520	349	80	389	660
230	1000	270	200	310	515	350	100	390	2600
231	1220	271	630	311	493	351	110	391	2200
232	1240	272	910	312	520	352	120	392	790
233	1300	273	450	313	520	353	290	393	600
234	1880	274	570	314	550	354	850	394	700
235	360	275	950	315	475	355	1400	395	540
236	570	276	710	316	397	356	640	396	640
237	370	277	670	317	430	357	660	397	680
238	420	278	260	318	520	358	250	398	500
239	270	279	380	319	370	359	110	399	490
240	650	280	360	320	530	360	60	400	130

Farmer No.	K	Farmer No.	K	Farmer No.	K	Farmer No.	K	Farmer No.	K
401	230	441	480	481	260	521	180	561	1120
402	650	442	680	482	340	522	120	562	360
403	810	443	840	483	600	523	210	563	1060
404	130	444	1600	484	680	524	380	564	480
405	820	445	655	485	180	525	100	565	290
406	730	446	240	486	350	526	250	566	400
407	960	447	370	487	625	527	260	567	410
408	840	448	180	488	250	528	130	568	720
409	680	449	600	489	60	529	150	569	1120
410	620	450	110	490	700	530	750	570	1180
411	380	451	280	491	1180	531	290	571	360
412	520	452	180	492	1500	532	440	572	660
413	840	453	390	493	890	533	420	573	170
414	50	454	270	494	495	534	620	574	120
415	70	455	120	495	60	535	1420	575	650
416	270	456	210	496	140	536	1060	576	1650
417	230	457	120	497	900	537	1700	577	1600
418	150	458	250	498	500	538	190	578	320
419	160	459	180	499	270	539	90	579	3300
420	90	460	280	500	140	540	360	580	610
421	400	461	300	501	530	541	160	581	460
422	140	462	320	502	210	542	540	582	300
423	70	463	250	503	130	543	660	583	350
424	60	464	210	504	100	544	480	584	560
425	350	465	200	505	450	545	540	585	400
426	290	466	80	506	460	546	510	586	900
427	830	467	160	507	260	547	550	587	560
428	490	468	265	508	750	548	860	588	300
429	620	469	230	509	150	549	650	589	80
430	170	470	330	510	260	550	690	590	520

431	230	471	240	511	295	551	640	591	330
432	430	472	220	512	182	552	180	592	390
433	300	473	670	513	180	553	180	593	440
434	280	474	840	514	390	554	330	594	1080
435	440	475	220	515	280	555	550	595	560
436	320	476	145	516	230	556	550	596	170
437	570	477	345	517	400	557	420	597	480
438	260	478	546	518	430	558	720	598	170
439	150	479	560	519	210	559	700	599	380
440	550	480	440	520	230	560	280	600	150

Table 2 The data base used developed for input and output parameters in grape vineyard

Obs.No.	INPUT(K) (ppm)	OUTPUT			
		Organic before pruning (Kg/acre)	Inorganic Before Pruning (Kg/acre)	Inorganic 30-60 days after pruning (Kg/acre)	Inorganic 105-135 days after pruning (Kg/acre)
	Potassium	Natural Potassium	Artificial Potassium 1	Artificial Potassium 2	Artificial Potassium 3
1	100	84	5	63	63
2	200	70	5	53	53
3	300	62	5	46	46
4	450	56	5	42	42
5	600	56	5	42	42
6	650	51	5	38	38
7	700	45	5	34	34
8	750	39	5	29	29
9	800	34	5	25	25
10	2000	28	5	21	21
11	2200	23	5	17	17

Note: K: Potassium, NL: NaturalPotassium, AK1: Artificial Potassium 1, AK2: Artificial Potassium 2, AK3: Artificial Potassium 3.

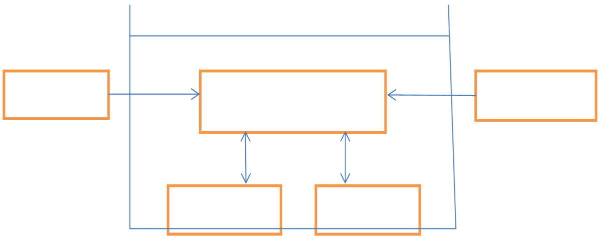

Fig.1 Block diagram of Fuzzy Inference System

Input and output variables of Fuzzy Inference System are shown in Fig.2

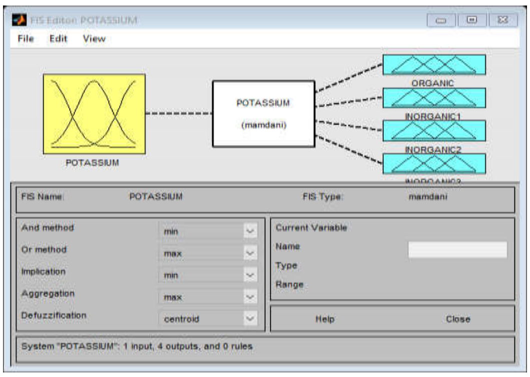

Fig.2 Fuzzy Inference System

Fuzzification: It is the process of conversion of precise quantity to a fuzzy quantity which is the first step in Fuzzy inference System. It includes Data base and Rule base.

Data Base: The fuzzy system represents structured information in the form of a fuzzy set (FS). The input and output universe are modeled using FS [11]. It consists of fuzzy domains such as: MOL (Most Low), VL (Very Low), JL(Just Low), ML (Moderate Low), L (Low),N (Normal), H **(**High), MH (Moderate High), JH (Just High), VH (Very High), MOH (Most High).

Potassium domain is used as input for FIS which may carry out the Fuzzification for suggestion of Potassium to the soil specific vineyard. The suggestion of Potassium varies in the range of 100 kg/acre to 2200 kg/acre. The eleven fuzzy sets for input variable Potassium are shown in Table 3.

Table 3 Fuzzy Set for input variable Potassium

Sr.No.	Potassium Measured (Membership Function)	Fuzzy sets for Potassium (kg /acre)
1	μ_{MOL}	L(100, 100, 200)
2	μ_{VL}	Λ(100, 200, 300)
3	μ_{JL}	Λ(200, 300, 450)
4	μ_{ML}	Λ(300,450, 600)
5	μ_{L}	Λ(450, 600, 650)
6	μ_{N}	Λ(600, 650, 700)
7	μ_{H}	Λ(650, 700, 750)
8	μ_{MH}	Λ(700,750, 800)
9	μ_{JH}	Λ(750, 800, 2000)
10	μ_{VH}	Λ(800, 2000, 2200)
11	μ_{MOH}	(2000, 2200, 2200)

Depending upon the potassium value in the soil of individual garden, the doses of Potassium through organic and inorganic grades are to be supplied. The linguistic values for suggested Potassium are chosen as: MOH (Most High), VH (Very High), JH(Just High), MH (Moderate High), H (High), N (Normal), L **(**Low), ML (Moderate Low), JL (Just Low), VL (Very Low), MOL (Most Low). The values of NL are within the range of 23-84 kg/acre. Here AK1 is constant as 5 kg/acre, while AK2 and AK3 range is from for 17-63 kg/acre. It is shown in table 4.

Table 4 Fuzzy set for output variableOrganic (NL) and Inorganic fertilizer (AP2 and AP3)

Obs. No.	Organic and Inorganic fertilizer (Membership Functions)	Fuzzy set		
		Basal Organic before pruning(NL) (kg /acre)	Inorganic 30-60 days after pruning(AP2) (kg /acre)	Inorganic 105-135 days after pruning(AP3) (kg /acre)
1	μ_{MOH}	L (84, 84, 70)	L (63, 63, 53)	L (63, 63, 53)
2	μ_{VH}	Λ (84, 70, 62)	Λ (63, 53, 46)	Λ (63, 53, 46)
3	μ_{JH}	Λ (70, 62, 56)	Λ (53, 46, 42)	Λ (53, 46, 42)
4	μ_{MH}	Λ (62, 56, 56)	Λ (46, 42, 42)	Λ (46, 42, 42)
5	μ_{H}	Λ (56, 56, 51)	Λ (42, 42, 38)	Λ (42, 42, 38)
6	μ_{N}	Λ (56, 51, 45)	Λ (42, 38, 34)	Λ (42, 38, 34)
7	μ_{L}	Λ (51, 45, 39)	Λ (38, 34, 29)	Λ (38, 34, 29)
8	μ_{ML}	Λ (45, 39, 34)	Λ (34, 29, 25)	Λ (34, 29, 25)
9	μ_{JL}	Λ (39, 34, 28)	Λ (29, 25, 21)	Λ (29, 25, 21)
10	μ_{VL}	Λ (34, 28, 23)	Λ (25, 21, 17)	Λ (25, 21, 17)
11	μ_{MOL}	(28, 23, 23)	(21, 17, 17)	(21, 17, 17)

Membership function for input variable Potassium measured in soil is shown in Fig.3.

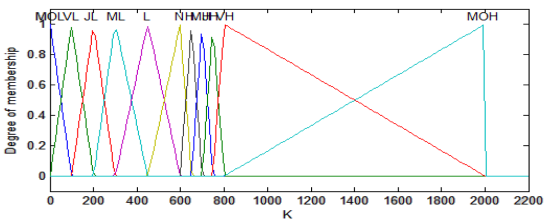

Fig 3 Fuzzy membership function for Potassiummeasured

Membership functions for output variables i.e. Organic Potassium, Inorganic Potassium1, Inorganic Potassium 2 and Inorganic Potassium 3 are shown in Fig.4a, 4b, 4c respectively.

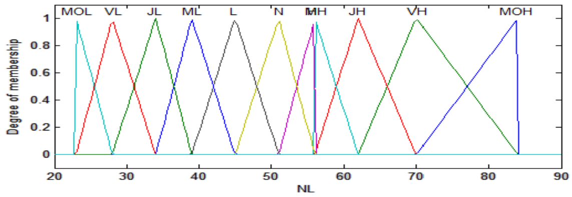

Fig 4a Fuzzy membership function for Organic Potassium (NL) suggested

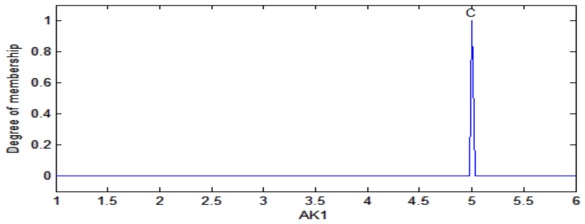

Fig 4b Fuzzy membership function for Inorganic Potassium (AK1) suggested

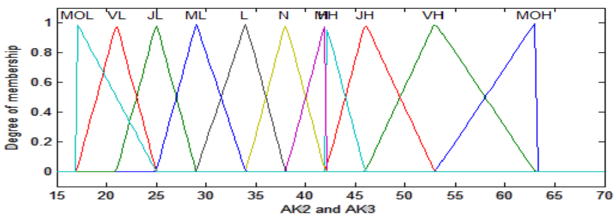

Fig 4c Fuzzy membership function for Inorganic Potassium (AK2 and AK3) suggested

Fuzzy Rule base: In this rule base, 11 rules are developed by researcher and shown in table 5.

The fuzzy rule base is read as

If Potassium is Most Low Then Natural Potassium is Most High and Artificial Potassium1 is constant and Artificial Potassium2 and Artificial Potassium3is Most High.

Fig.5 shows the GUI rule base of MATLAB.

Work flow of FIS: FIS.PS works according to the flow chart as shown in fig.6.

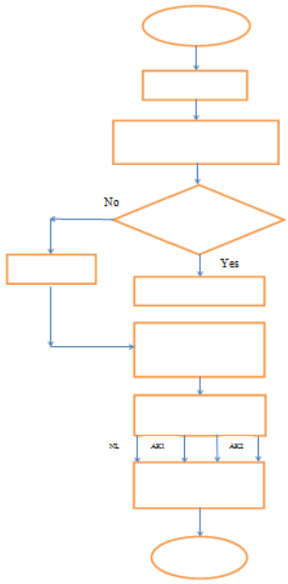

Fig.6 Work flow of FIS

Defuzzication: It is the process of conversion of fuzzy quantity to a precise quantity.

Here centroid Defuzzification method is used and shown in fig.7.

Table 5 The fuzzy rule base developed is given below.

If K is	**MOL**	**Then NL is**	**MOH**	**And AK1 is**	**C**	**And AK2 is**	**MOH**	**And AK3 is**	**MOH**
	VL		**VH**		**C**		**VH**		**VH**
	JL		**JH**		**C**		**JH**		**JH**
	ML		**MH**		**C**		**MH**		**MH**
	L		**H**		**C**		**H**		**H**
	N		**N**		**C**		**N**		**N**
	H		**L**		**C**		**L**		**L**
	MH		**ML**		**C**		**ML**		**ML**
	JH		**JL**		**C**		**JL**		**JL**
	VH		**VL**		**C**		**VL**		**VL**
	MOH		**MOL**		**C**		**MOL**		**MOL**

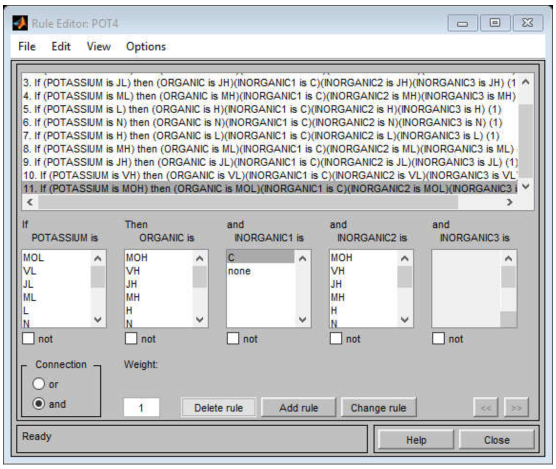

Fig. 5 Rule base for inference system

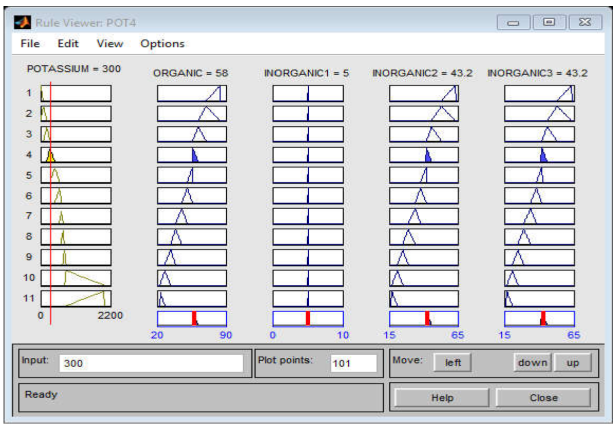

Fig.7 Defuzzication is shown in fig.

Practical Results for Suggestion of NL, AK1, AK2 and AK3

The data given in the table 6 shows suggested value for natural and artificial potassium based on the status of potassium available in the soil samples of different farmers. The data suggested by FIS gives requirement of exact quantity of fertilizer during the season. This can help to save cost of fertilizer and produce more yields.

Surface Viewer

The Surface Viewer is a GUI tool that examines the output surface of a stored in a file, a.fis, for any one or two inputs. It gives the nonlinear relationship between input and output.

Table 6 Suggestion of NL, AK1,AK2 and AK3

Sr.No.	Farmer No.	Input Data (ppm)	Potassium suggested by Expert			Potassium suggested by FIS		
			NL (kg/acre)	AK1 (kg/acre)	AK2 and AK3 (kg/acre)	NL (kg/acre)	AK1 (kg/acre)	AK2 and AK3 (kg/acre)
1	489	60	84	5	63	74.37	5	55.67
2	476	145	84	5	63	74.37	5	55.67
3	168	200	70	5	53	68.38	5	50.26
4	481	260	70	5	53	68.38	5	50.26
5	292	310	62	5	46	60.66	5	44.37
6	583	350	62	5	46	60.66	5	44.37
7	544	480	56	5	42	54.03	5	40.53
8	690	550	56	5	42	54.03	5	40.53
9	549	650	51	5	38	49.66	5	36.99
10	475	650	51	5	38	49.66	5	36.99
11	254	660	51	5	38	49.66	5	36.99
12	550	690	51	5	38	49.66	5	36.99
13	394	700	45	5	34	43.41	5	32.66
14	32	760	39	5	29	37.91	5	27.42
15	59	890	34	5	25	32.14	5	23.58
16	77	1400	34	5	25	32.14	5	23.58
17	380	1460	34	5	25	32.14	5	23.58
18	95	1480	34	5	25	32.14	5	23.58
19	576	1650	34	5	25	32.14	5	23.32
20	579	3300	23	5	17	23	5	17

Phosphorus suggested by FIS gives better result as shown in graph fig.8a and 8b.

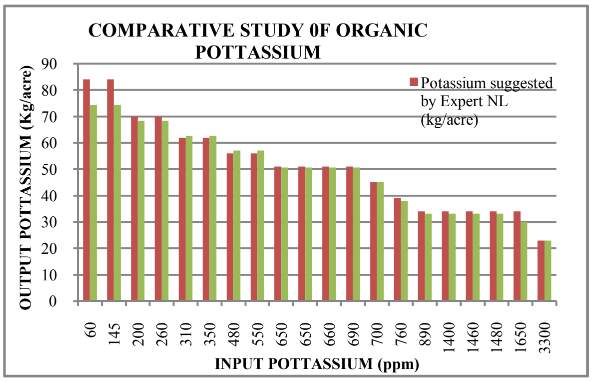

Fig.8a Comparative study of Organic potassium (NL)

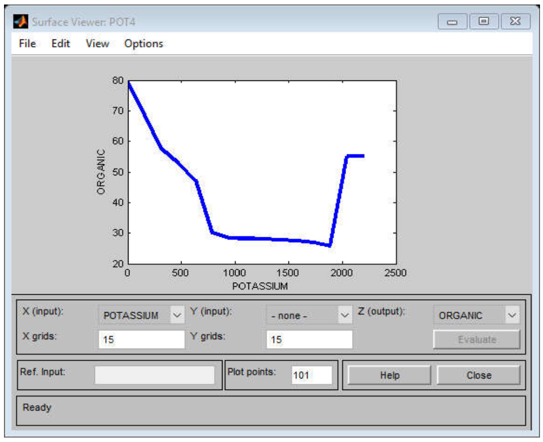

Fig.8a Surface viewer of the system

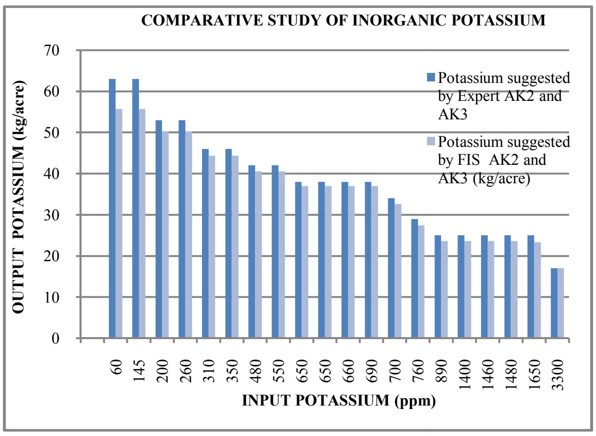

Fig.8b Comparative study of Inorganic potassium (AK2 and AK3)

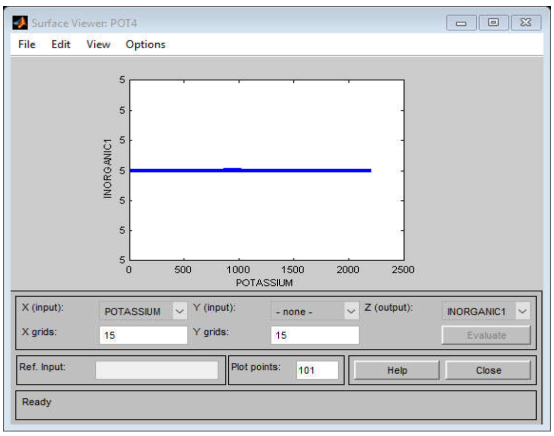

Fig.8b Surface viewer of the system

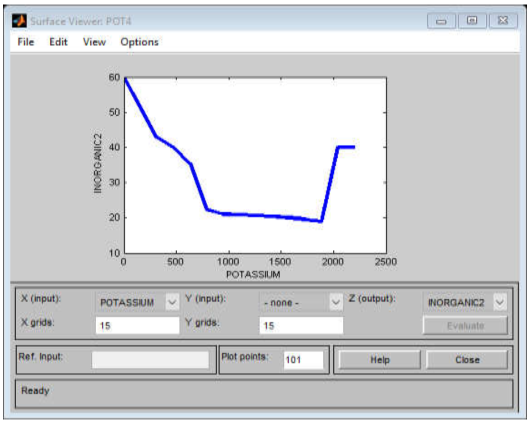

Fig.8c Surface viewer of the system

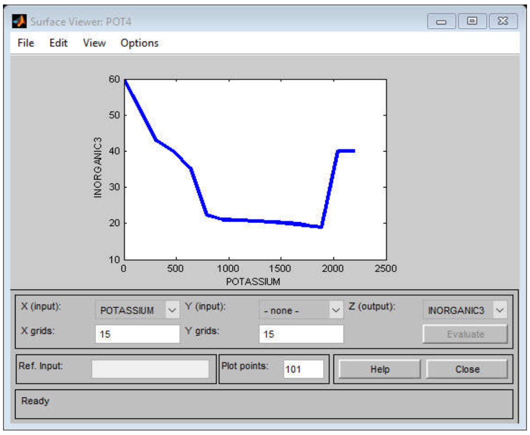

Fig.8d Surface viewer of the system

CONCLUSION

Laboratory expert does not indicate exact quantity of fertilizer Potassium to be used for the soil. The FIS system helps to suggest the accurate quantity of Potassium used for the soil. This reduces the cost of production of grapes and it also increases the yield.

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