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Establishment theoretical of recommendation fertilization guide of vegetable crops in Algeria: concept and validation

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ABSTRACT

The goal of fertilization is to meet the nutritional needs of plants by completing the supply of soil nutrients in an economically profitable and environmentally friendly.Achieving on-farm optimum economic crop yields of marketable quality with minimum adverse environmental impact requires close attention to fertilization guide. The recommendations seek to do this by ensuring that the available supply of plant nutrients in soil is judiciously supplemented by additions of nutrients in fertilizers. The objective is that crops must have an adequate supply of nutrients, and many crops show large and very profitable increases in yield from the correct use of fertilizers to supply nutrients. The main objective of this work is to establishing a reference guide of fertilization of vegetable crops and cereal in Algeria. To meet this objective, we have processes in two steps: 1) Establishment of theoreticalfertilizer recommendation from international guide of crop fertilization; 2) Validation of these developedtheoreticalfertilizer recommendationby trials in the fields.Sixteen fertilization guides of vegetable crops from the Canadian provinces (5 guides), USA (10 guides) and countries of northern Europe England (1 guide). Generally, the rating of these recommendation is ranging from poor soil to soil exceedingly rich; however, the numbers of fertility classes are very different. Indeed, Quebec Ontario, Minnesota, Wisconsin New England, Maryland and Kentucky and Florida guides are subdivided into 5 fertility classes, ranging from poor soil to soil exceedingly rich. The recommendation of New Brunswick and Manitoba contain six classes. The recommendation of Michigan, Nova Scotia and England contain 10 and 7 fertility classes respectively. The recommendation fertilizer of New York and New Jersey have 3classes. Unlike the systems of fertilization recommendation mentioned above, the recommendation fertilizer of Pennsylvania is based on continuous models of P, K and contains 34 classes for P and 22 classes K.Then we standardized the P soil analysis with conversion equations (Olsen method) and units of measurement (kg/ha, mg/kg…).Following this procedure we transformed discontinued systems of fertility classes in to continuous models to facilitate comparison between the different fertilization recommendation models in one hand, in other hand to obtain critical value (CV).Finally, we used statistics of the conditional expectation in order to generate the theoretical recommendation fertilization guide of fertilization with *7 fertility classes* (VL, L, M, MH, OP, H and VH). The next step was calibrating soil tests against yield responses to applied nutrient in field experiments. A database (not published data) from agriculture and agri-food Canada, were used. Production of pumpkin responded positively and significantly to P or K soil fertility levels, increases being observed with P more often than with K. According to the Cate-Nelson methods, the critical value of Olsen-P in the top 20 cm of soil was about 25mg/kg: at values of greater than or equal to 25mg/kg, crops achieved about 80% of their maximal yield in the absence of fertilizer application. The CV of K in soil for this crop was about 140mg/kg. The CV found was very close to this generated by the theoretical method for recommendation of fertilization guide. Finally, we used the procedure of Cope and Rouse in both sides of the CV in order to make subdivisions of different groups of soil fertility. One calibrates the soil-test value against yield response to tile nutrient to predict fertilizer requirement.

Keywords: Fertilization recommendation; NPK-fertilization; critical value; vegetable crops.

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INTRODUCTION

According to FAO, over the past 50 years, the increase in world agricultural production was 1.6 times greater than 10000 years of agricultural history. This shows the importance of the contribution of science to the development of agriculture. Nutrient management is a key factor in the success or failure of cropping systems in Algeria. Insufficient nutrient levels can decrease yield and quality by creating a stressed environment where plants are more susceptible to disease and weed infestation. However, excessive nutrient levels can also reduce crop productivity, quality and farmers profitability (Tindall et al.,1997).Proper nutrition is essential for satisfactory crop growth and production. Crop Fertilizer recommendations based on soil tests take into consideration the fertility level of individual fields. If the soil in a particular field is already high in a nutrient, as determined by soil test, a low application will be recommended and vice versa. In this way limited capital or resources can be used on fields where they will do the most good. Excessive fertilizer use, especially nitrogen and phosphorus, has potential to degrade ground and surface water quality (Dahnke et al., 1992).The use of soil tests can help to determine the status of plant available nutrients to develop fertilizer recommendations to achieve optimum crop production. The profit potential for farmers depends on producing enough crops per hectare to keep production costs below the selling price. Efficient application of the correct types and amounts of fertilizers for the supply of the nutrients is an important part of achieving profitable yields.

The fertilizer industry supports applying nutrients at the right rate, right time, and in the right place as a best management practice for achieving optimum nutrient efficiency (Roberts, 2008). Determining the optimal fertilizer rate for each vegetable crop and cereal can be challenging. Currently, many farmers in Algeria use NPK fertilizers but have little information on which to base their decisions on how much to apply. The result is that many of the soils receive more fertilizer than can be used by the crop, and the unused portion is either lost or accumulated in the soil. For example, in some soils that have been fertilized yearly at rates recommended by agricultural ministries, the available phosphorus determined by the Olsen test has risen to about two or three times the amount needed for maximal yields of wheat, according to studies to date. Bringing the application rates more in line with crop requirements could save hundreds of thousands of tons of fertilizer each year.Thus, for instance, Algerian ministry of agricultural suggest simple recommendation for cereal whatever soil-test value; 100kg P_2O_5/ha are available, 100kg N-sulphate/ha or 80kg urea/ha). However, for vegetablecrops fertilization no data are available, thecrop fertilization is left for farmers. However, FERTIAL Spa, Algeria have launched a very good initiative which is to make free soil testing for farmers.

The most economical means of determining the fertilizer needs of cereal and vegetable soils is to have soil analysis. This means that productive agriculture should first solve the problem of under/over fertilization. This implies a profound reflection on the different farming practices and development of fertilization recommendation. Soil testing remains one of the most powerful tools available for determining the nutrient supplying capacity of the soil, but to be useful for making appropriate fertilizer recommendations good calibration data is also necessary. One of the efficiency approaches to making fertilizer recommendations which is based on the concept that a nutrient should be applied only if there is a reasonable expectation of a crop response. Under this approach, fertilizers should be applied only if they increase yields, and then only at optimum rates.The soil test will provide the basis for fertilizer application rates. One of the main problems hindering the development of Algerian agriculture and his economic success is the slightly-use of fertilizers. So far Algeria has neither the scientific tools (suchas diagnostic and analytical) or fertilizer recommendation guide for vegetable and cereal.Therefore the development of fertilization recommendation is the best options for optimize vegetables and grain production for Algerian market. The only references (recommendations) in fertilizing crops available to the Algerian agriculture are given by the company FERTIAL as only an indicative tool.The target of fertilization recommendation is to guideextension educators to provide help for farmers to interpret the soil test results. In addition to helpthem to decide how much fertilizer to apply.A controlled fertilization program of this nature also minimizes the potential for soil damage and water pollution. In other hand, the reduced nutrient use efficiency or losses in yield and crop quality by over- or under-application of fertilizer will be minimized. Good nutrient management is essential to helping farmers grow the food we want to buy without harm to the environment or health: farming can produce food and other crops profitably, sustainably and with high environmental standards.

The objectives of this work include:

1. An inventory and synthesis of recommender systems for N, P and K available for vegetable nationally and internationally.
2. A proposed recommendation models for some vegetable crops (theoretical model).
3. Validation of proposed fertilizer recommendation by Field Trials preparation and fertilization final recommendation for vegetable crops.
4. Produce a manual in order to help farmers and land managers better assess the fertilizer required for the range of crops they plan to grow, by suggesting what level of nutrients are required to provide the best financial return for the farm business. The manual will help ensure that proper account is taken of both mineral fertilizers.

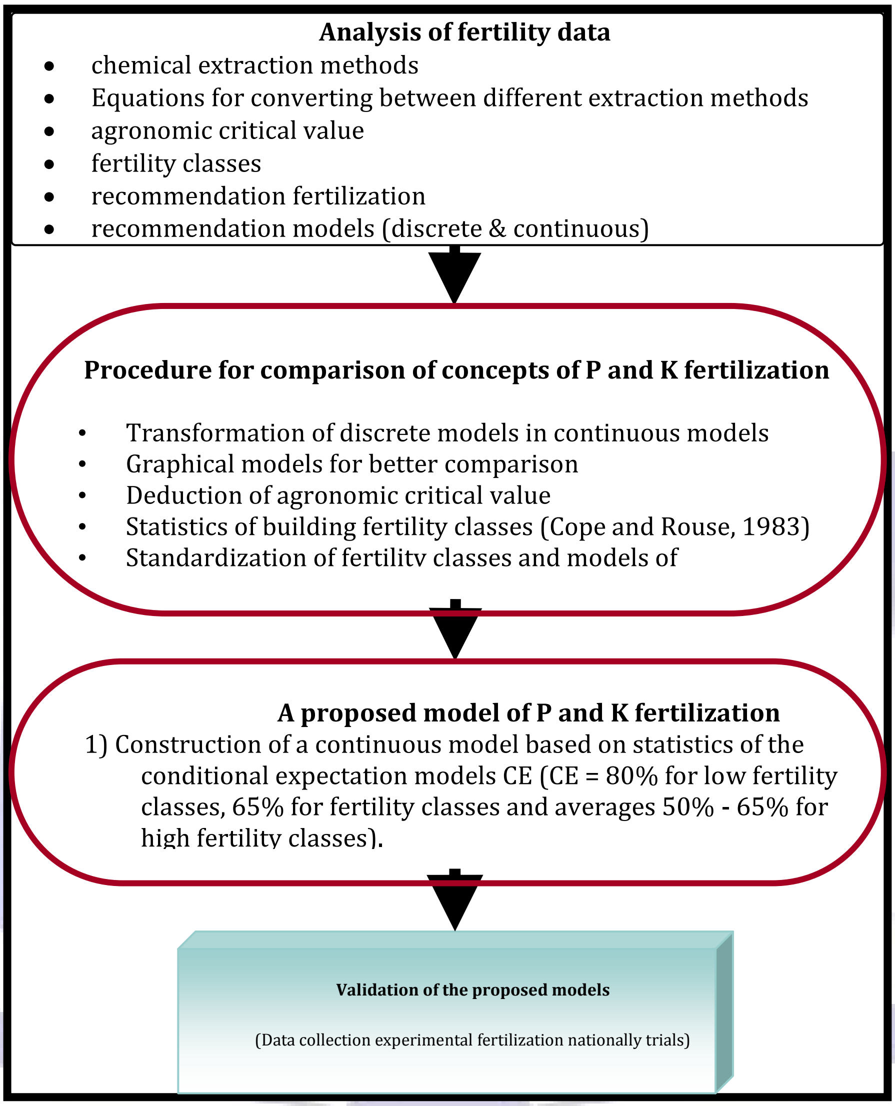
MATERIALS AND METHODS

I) ESTABLISHMENT OF THEORETICAL RECOMMENDATION OF FERTILIZATION

For the development of fertilization recommendation guide, two approaches are possible:

1. The development of theoretical recommendation of fertilization followed by field validation and soil calibration;
2. Conduct large scale of NPK fertilization experiments after soil calibration.

According to Dr.Tremblay researcher at Agriculture and Agri-food Canada (personal communication) the first approach allows the gain time and cost of experimentation, so we consider the first procedure, since it will allow us to develop a theoretical framework followed by field trials for validation. And also allow us to define the intervals of nutritional adequacy of different cultures.A schema 1 summarize all steps of procedure to elaborate theoretical of fertilization recommendation guide.



Schema 1: general procedure to elaborate theoretical fertilization recommendation guide.

II) VALIDATION OF THESE DEVELOPED THEORETICAL FERTILIZER RECOMMENDATION BY TRIALS IN THE FIELDS.

The research base is developed from research projects in which measured yields are related to soil test values for the nutrient of interest and the rate of that nutrient that has been applied.We used a database from Agriculture and Agri-food Canada (AAC) and Ministère de l'Agriculture, des Pêcheries et de l'Alimentation Québec (MAPAQ)derived from a large fertilization trials of vegetable crops (pumpkins; *Cucurbita maxima*) and soils calibration across Quebec province (Canada) from 2001 to 2003. We received this data as part of our study on: ⋘the changes made on the fertilization recommendation guide of vegetable crops of Quebec⋙ (Sbih and Khiari, 2005). The soil samples collected before planting in fall 2001 Soil samples were collected in a systematic grid at 27 sites to a depth of 0-20 cm, The A composite soil sample was taken for each location. The soil samples were packed into plastic bags, then the soil samples were air dred and ground to pass through a 2-mm sieve, and analyzed for total N (Bremner and Mulvaney, 1982)., available P,K, Ca, Mg, Al, B, Cu, Fe, Mn, Zn, and Na was determined Mehlich III (Mehlich, 1984). The soil texture of surface layers ranged from clay loam to sandy soil.

Table 1: soil mineral analysis and pumpkins yield

	Soil Test												Pumpkin yield
	N Total	P Olsen	K	Ca	Mg	Al	B	Cu	Fe	Mn	Zn	Na	
	(%)	mg/kg											T/ha
Number	27	27	27	27	27	27	27	27	27	27	27	27	27
mean	2,56	28	70	4697	3058	168	28	12	155	17	33	265	23,7
min	1,68	1,4	24	1323	1682	28	19	6	42	8	9	67	39,0
max	3,52	77,8	160	42160	7024	1714	45	19	1659	33	52	669	1,716
SD	0,50	21,2	32	3079	674	142	7	3	128	5	8	100	11,92
VC	0,19	0,75	0,44	0,66	0,22	0,85	0,26	0,29	0,83	0,28	0,24	0,38	0,49

Statistics

The Cate-Nelson method is to plot the relative yield (0-100%) of pumpkin against the level of available P or K in the soil. The relative yield for each location is the total dry matter obtained in the treatments without fertilizer as a ratio of maximum yields obtained when fertilizer is added.

One incorporated the responses to P for treatment combinations that provided adequate N nutrition of the crop and one incorporated the responses to N when adequate P was available in the treatment. Soils were divided according to the probability (high or low) that pumpkin will respond to fertilization. The diagram of the results is divided into quadrants that maximize the number of points in the positive quadrants and minimize the number in the negative quadrants.

RESULTS AND DISCUSSION

I: DATA ANALYSIS OF INTERNATIONAL RECOMMENDATION GUIDE

In the first step we analyzed 16 fertilization guides of vegetable crops from the Canadian provinces (Quebec, Manitoba, Ontario, New Brunswick and Nova Scotia), of American States (New England, New York, New Jersey, Pennsylvania, Maryland, Michigan, Minnesota, Kentucky, Wisconsin and Florida) and countries of northern Europe (England). Generally, the fertilization guide of Quebec, Ontario, Minnesota, Wisconsin and Florida have five fertility classes, ranging from poor soil to soil exceedingly rich. The recommendation of New Brunswick and Manitoba contain six classes. The recommendationguide of Michigan, Nova Scotia and England contain 10 and 7 fertility classes. The states of New England, Maryland and Kentucky have four recommendation fertility classes, the recommendationguide of New York and New Jersey hasonly 3 classes. Unlike the systems mentioned above recommendations, the recommendation guide of Pennsylvania is based on continuous models of recommendation of P and K and contains 34 classes for P and 22 classes K, this is why we took the Pennsylvania model as reference. The above tables illustrate the different types of Pa and K recommendations guide.

Tool for P and K analysis standardization

Methods of chemical extraction of P and K and their conversion equations to make comparable fertility classes, we used a data conversion mining models with P conversions proposed by Tran and Giroux (1989) and Mallarino (1995) (Table 1). These conversions will redefine the fertility classes for each crop, taking into account the conversion of the unit of measurement. For potassium, the extraction with ammonium acetate is equivalent to MehlichIII, therefore, the fertility classes of K remains unchanged regardless of the method of extraction of potassium. The table 1 summarizes the conversion equations for phosphorus analysis.

Table 1: Equations of conversion

Equations	Authors
Mehlich-3 P = 2,63P-Olsen+4,3	Tran et Giroux 1989
P-Olsen = 0,46 Mehlich-3 P + 1,5	Mallarino, 1995
P-Olsen = 0,42 P-BrayI + 3,5	Mallarino, 1995
Mehlich-3 P = 14.8 + 1.54 P-Olsen	Kleinman et al., 2001
P-Olsen = 5.69 + 0.46 Mehlich-3 P	Kleinman et al., 2001
Bray-1 P = 13.5 + 1.34 Olsen P	Kleinman et al., 2001

Mehlich-3 P: P extraction methodMehlich-3;Mehlich-1 P: P extraction methodMehlich 1; P-BrayI: P extraction method (BrayI)

Critical value

Following the standardization procedure of recommendation fertilization, we transformed recommender systems in continuous models to facilitate comparison between the different fertilization recommendation models (U.S. states, Canadian provinces, England). The critical value were defined as the point marking the change of rate of the recommended dose based on the richness of the soil P or K (slope change) of the continuous model or the median of the class of medium fertility for models of constant slope like Quebec recommendation fertilization. The figure 1 is an illustration of this stage of the procedure.

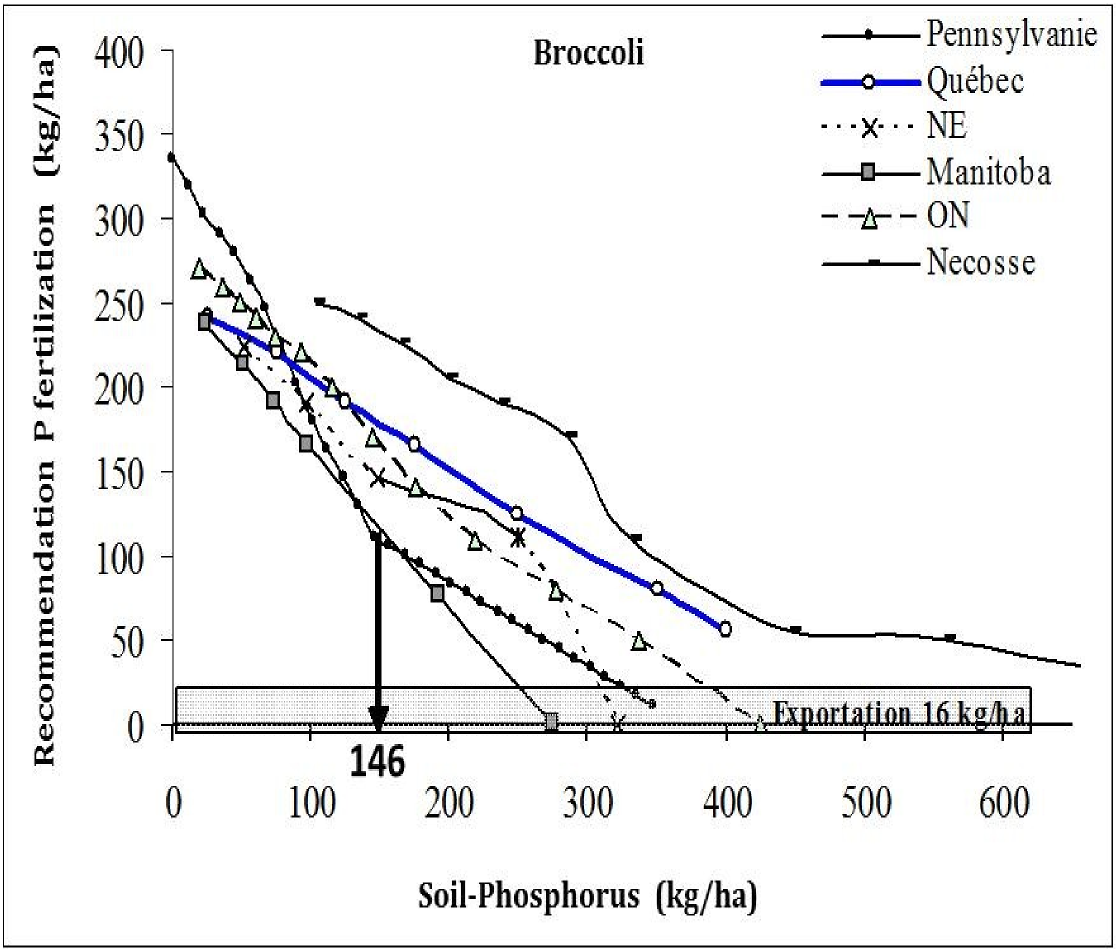


Figure1: Graphical representation of the different models of P Recommendation fertilization of broccoli crop

This figure shows the evolution of optimal doses of P_2O_5 for growing broccoli according to the richness of the soil P (continuous model). éIt shows a critical point of the model of Pennsylvania abscissa soil-P = 146 kg ha^{-1} marking the change in the rate of change in the recommended dose of 16 to 5 kg ha^{-1} of P_2O_5 per change of 10 kg ha^{-1} of soil-P. According to the model ofMitscherlich Bray,this point is the critical value beyond which there is a stable yield. This value is very close to 150 kg ha^{-1}soil-P, the median of phosphate soil fertility in Quebec (CRAAQ, 2003). However, the Quebec model keeps the same rate of change of 5 kg ha^{-1} of P_2O_5 per change of 10 kg ha^{-1} of soil-P whatever the class of phosphate fertility of soils. This trend does not subscribe to the principles of less than proportional decrease of recommendation fertilizer in the category of high fertility class.As the definition of fertility classes varies from one to anothersystem, we opted for uniform intervals of fertility by a graphical approach to the transformation of discrete models in continuous models.

This graphical approach has allowed us to develop equations with which it became possible to create new recommendations in phosphorus and potassium (Table 2). Previously, we have divided into intervals of indices of available P in both sides of the critical value, dividing this value by 2 and 4 for the very poor class and poor, and then multiplying by 2 and by 4 for the medium and rich by the procedure of Cope and Rouse (1983). Thus the obtained values are: 37.5 - 75 - 150 - 300 - 600 kg ha^{-1}soil-P (Table 2) we have inserted the value of 450, which is an intermediate value between 300 and 600 kg P/ha and represent value in which the Pennsylvania model recommendation is equal to zero. We recalculated the corresponding recommendations of P_2O_5in these subdivisions. The results obtained with the new recommendations are given in Table 2. Subsequently, we computed descriptive statistics such as, mean, standard deviation, maximum, minimum and coefficient of variation on all the recommendations by fertility class.

Table 2: Equations of different continue models of Phosphorus recommendation fertilization

	Equations of recommandation models				Formulation					
	Y = a x3 + bx2 + cx + d				(C1) 37.5	(C2) 75	(C3) **150**	(C4) 300	(C5) 450	(C6) 600
États	a	b	c	D	P_2O_5 kg ha^{-1}					
Pennsylvania	-4.00E-06	0.0048	-2.1294	351.61	**278**	**217**	**127**	**37**	**11**	**11**
Québec		8.00E-05	-0.5333	255.71	236	216	178	103	55	55
New York			-0.4001	157.16	142	127	97	37	0	0
N. Jersey		0.0008	-1.3067	252.97	205	159	56	56	56	56
N. England	-3.00E-05	0.0138	-2.6223	329.79	249	198	146	0	0	0
Kentucky		-0.0035	-1.6555	196.64	130	53	17	17	17	17
Michigan		0.0005	-1.0901	254.19	214	175	102	0	0	0
Minnesota		-0.0095	-1.5346	288.38	217	120	56	56	56	56
Florida		-0.0047	-0.4668	194.6	170	133	19	0	0	0
Manitoba		0.0002	-1.0002	262.52	225	189	117	0	0	0
Ontario		0.0006	-0.9305	293.25	259	227	167	68	0	0
N. Brunswick			-0.9481	233.39	198	162	91	90	90	90
N. Scotia		0.0001	-0.3924	340.78	326	312	284	232	184	141
Great Britain										
Maryland			-0.603	213.99	191	169	124	33	27	27
Wisconsin	-3.00E-05	0.0151	-2.3544	130.22	62	26	16	0	0	0
Min					62	26	16	0	0	0
Max					326	312	284	232	184	141
standard deviation					64	70	72	61	51	42
Mean					207	166	106	49	33	30
CV					31	42	67	126	153	139
conditional expectation at 50 %					***217***	***175***	***102***	***37***	***11***	***11***
conditional expectation at 65 %					***222***	***182***	***120***	***47***	***22***	***22***
conditional expectation at 80 %					***249***	***216***	***146***	***68***	***56***	***56***

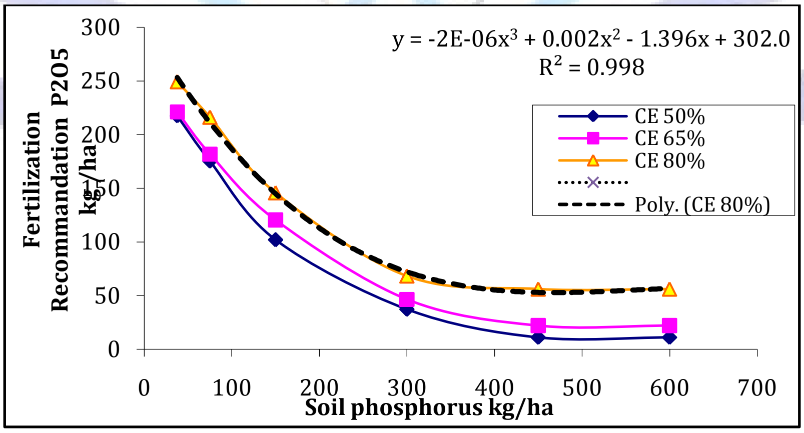
C1 : classe 1 = (C3)/4; C2 : classe 2 = (C3)/2; C3 : classe 3; C4 : classe 4 = (C3) x 2 ; C5 classe 5 = (C4) +150; C6 : classe 6 = (C3) x 4.

C3 : Represent the critical value in the recommended dose according to the model Mitscherlich and Bray (Pennsylvania recommendation guide)

As recommended doses vary from one to anothersystem, we proposed a dose recommendations representative of a chance to cover the cases identified in each fertility class through the recommendationsystems used in this study. A conservative approach, covering 50% of cases identified in each fertility class (the class average) and a more liberal approach, covering 80% of cases in a class of fertility, these approaches can be used as decision aid to determine the dose of P_2O_5 and K_2O to recommend as agronomic indicators for P and K (Fig. 2). The difference between the approaches should demonstrate the importance of considering the variation of agronomic criteria (yield potential, planting density, cultural practices, cultivar ...) soil (soil sorbtion capacity, type of colloidal matter ...) climate (rainfall, temperature, irrigation ...) from one system to another.

Elaboration of new P recommendation fertilization

Then the obtained value with Conditional Expectation at 80% were used in order to elaborate a continue model as showed in figure 2. The parameters of the equation generated by this value are used to elaborate the new fertilization recommendation



CE: Conditional Expectation

Figure 2: Probabilistic models to help change the recommendation of P fertilizer for growing broccoli

Table3: Equations of conditional expectation at 80%of phosphorus recommendation fertilization of broccoli

	Equations of conditional expectation at 80 %				elaborate new P fertilization recommendation for Broccoli		
	Y = a x3 + bx2 + cx + d						
Classe (x)	a	b	c	d	∑	mean	New girds
0	-2,00E-06	0,0026	-1,396	302,05	302	302	
50	-2,00E-06	0,0026	-1,396	302,05	239	(302+239)/2=270	270
100	-2,00E-06	0,0026	-1,396	302,05	186	(239+186)/2=212	210
150	-2,00E-06	0,0026	-1,396	302,05	144	(186+144)/2=165	165
200	-2,00E-06	0,0026	-1,396	302,05	111	(144+111)/2=128	130
300	-2,00E-06	0,0026	-1,396	302,05	63	(111+63)/2=87	90
400	-2,00E-06	0,0026	-1,396	302,05	32	(63+32)/2=47	50
450	-2,00E-06	0,0026	-1,396	302,05	18	(32+18)/2=25	25

Table 4: Phosphorus recommendations for broccoli (theoretical model of fertilization recommendation)

		Soil Test P level (mg/ha)						
	Olsen-P(ppm)	≤ 0-4	4-12	12-22	22-30	30-46	46-62	≥62
	Olsen-P (kg/ha)	≤0-10	10-28	28-50	50-68	68-104	104-144	≥144
		P_2O_5 to apply (kg/ha)						
Rating		*VL*	*L*	*M*	*MH*	*OP*	*H*	*VH*
Broccoli		**270**	**210**	**165**	**130**	**90**	**50**	**25**

Fertility classes: VL: very low; L: low; M: medium; MH: medium high; OP: optimum; H: high; VH: very high

Phosphorus recommendations for vegetable (theoretical model of fertilization recommendation guide)

	Soil Test P level						
Olsen-P(ppm)	≤ 0-4	4-12	12-22	***22-30***	30-46	46-62	≥62
Olsen-P (kg/ha)	≤0-10	10-28	28-50	50-68	68-104	104-144	≥144
Mehlich3-P(ppm)	≤22	23-45	46-67	68-89	90-134	135-179	≥180
Mehlich3-P(kg/ha)	≤50	51-100	101-150	151-200	201-300	301-400	≥401
	P_2O_5 to apply (kg/ha)						
Rating	*VL*	*L*	*M*	*MH*	*H*	*VH*	*EH*
Pumpkin	220	180	140	***110***	70	40	20
broccoli	270	210	165	130	90	50	25
onion	280	215	165	125	85	55	40
Garlic	250	190	140	105	70	40	20
leek	255	200	150	110	70	40	25
beet	200	170	135	110	75	45	35
Lettuce	220	180	150	120	85	50	35
cucumber	255	190	140	105	75	50	40
melon	235	185	145	110	80	65	50
peas	165	130	105	85	65	40	25
green bean	130	100	75	60	50	30	15
Lima-beans	150	120	100	75	55	35	25
cabbage	245	205	170	135	100	61	45
Cauliflower	250	205	165	135	100	70	60
radish	180	145	120	95	70	50	40
rutabaga	195	160	130	105	80	50	40
Carrot	180	150	125	100	75	50	45
Peppers	260	210	165	130	100	60	40
tomato	235	195	160	130	95	65	50
Eggplant	245	200	160	125	90	60	50

Fertility classes: VL: very low; L: low; M: medium; MH: medium high; OP: optimum; H: high; VH: very high

Model recommendation of potassium

We followed the same approach as for P. Figure 3 shows the evolution of optimal doses K_2O for growing broccoli according to the richness of soil K (continuous model recommendation of potassium). It shows a critical point of the model of Pennsylvania abscissa K = 292 kg / ha marking the change in the pace of change in the recommended dose of 31 to 10 kg K_2O per 10 kg of variation K_2O/ha. However, the Quebec model keeps the same rate of change, 36 kg K_2O per 10 kg variation K_2O/ha whatever the class of potassium fertility of soils. The results for the different models are shown in Table 5.

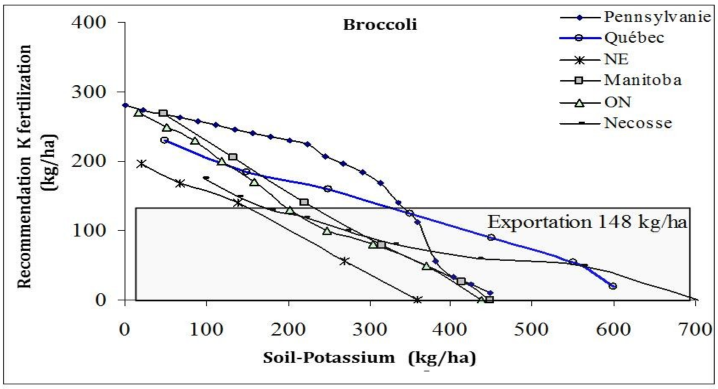
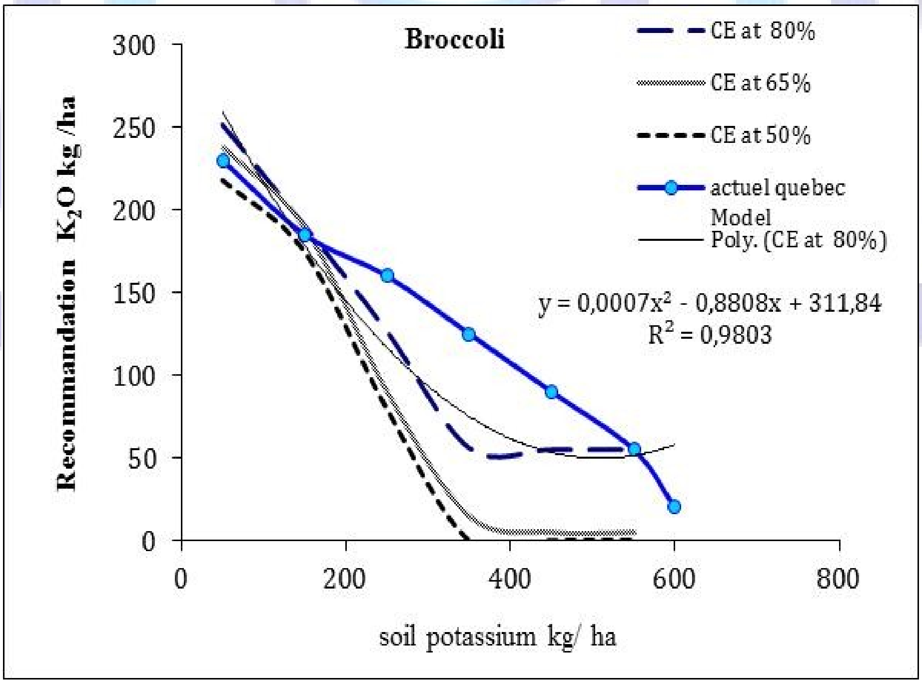


Figure 3: Graphical representation of the different models of K recommendation fertilization of broccoli crop

Table5: Equations of different continue models of potassium recommendation fertilization

	Equations of recommandation models				Formulation					
	Y = a x3 + bx2 + cx + d				(C1) 75	(C2) 150	(C3) **300**	(C4) 450	(C5) 600	(C6) 1200
States	a	b	c	D	K_2O kg ha^{-1}					
Pennsylvania	-3.00E-06	5.00E-05	-0.1392	275.43	**264**	**246**	**157**	**11**	**11**	**11**
Quebec	-1.00E-06	1.00E-03	-0.5727	255.75	218	189	147	109	56	55
New York			-0.6578	221.73	172	123	24	67	67	67
N. Jersey			-0.9347	265.37	195	125	56	56	56	56
N. England		-0.0004	-0.4392	203.29	168	128	36	0	0	0
Kentucky		-0.0001	-0.2855	173.96	152	129	79	0	0	0
Michigan		-0.0003	-0.7485	309.34	252	190	58	0	0	0
Minnesota		-0.0003	-0.4952	300.26	261	219	125	0	0	0
Florida		-0.0039	0.6287	132.46	158	139	0	0	0	0
Manitoba	-3.00E-07	0.0005	-0.8722	310.25	248	190	85	0	0	0
Ontario	-1.00E-07	0.0005	-0.8446	290.14	230	174	79	0	0	0
N. Brunswick	-2.00E-05	0.0133	-3.2553	446.06	268	190	126	70	70	70
N. Scotia		0.0002	-0.4315	205.79	175	146	94	52	19	0
Great Britain										
Maryland			-0.531	156.64	117	77	0	28	28	28
Wisconsin		-0.0006	-0.1795	264.75	248	224	157	0	0	0
								0		
Min					117	77	0	0	0	0
Max					268	246	157	106	70	70
standard deviation					49	46	53	26	28	28
Mean					208	166	82	26	20	19
CV					23	28	65	136	135	146
conditional expectation at 50 %					***218***	***174***	***79***	***0***	***0***	***0***
conditional expectation at 65 %					***239***	***189***	***90***	***26***	***15***	***6***
conditional expectation at 80 %					***252***	***190***	***126***	***56***	***56***	***55***

C1 : classe 1 = (C3)/4; C2 : classe 2 = (C3)/2; C3 : classe 3; C4 : classe 4 = (C3) x 2 ; C5 classe 5 = (C4) +150; C6 : classe 6 = (C3) x 4.C3 : Represent the critical value in the recommended dose according to the model Mitscherlich and Bray (Pennsylvania recommendation guide)



CE: Conditional Expectation

Figure 4: Probabilistic models to help change the recommendation of K fertilizer for growing broccoli

Table 6: Equations of conditional expectation at 80%of potassium recommendation fertilization of broccoli

	Equations of conditional expectation at 80 %				elaborate new K fertilization recommendation for Broccoli		
	Y = a x3 + bx2 + cx + d						
Classe (x)	a	b	c	d	∑	mean	
0	0,00E+00	0,0007	-0,8808	312	312	312	New girds
100	0,00E+00	0,0007	-0,8808	312	231	(312+231)/2=271	<u>270</u>
200	0,00E+00	0,0007	-0,8808	312	164	(231+164)/2=197	<u>200</u>
300	0,00E+00	0,0007	-0,8808	312	111	(164+111)/2=137	<u>140</u>
400	0,00E+00	0,0007	-0,8808	312	72	(111+72)/2=91	<u>90</u>
500	0,00E+00	0,0007	-0,8808	312	46	(72+46)/2=59	<u>60</u>
600	0,00E+00	0,0007	-0,8808	312	35	(46+35)/2=41	<u>40</u>
650	0,00E+00	0,0007	-0,8808	312	35	(35+35)/2=35	<u>35</u>

Table 7: Potassium recommendations for broccoli (theoretical model of fertilization recommendation)

	Soil Test K level (ppm)							
		≤45	46-89	90-134	135-179	190-223	224-268	≥269
	K_2O to apply (kg/ha)							
Rating		*VL*	*L*	*M*	*MH*	*OP*	*H*	*VH*
broccoli		270	200	140	90	60	40	35

Fertility classes: VL: very low; L: low; M: medium; MH: medium high; OP: optimum; H: high; VH: very high

Potassium recommendations for vegetable (theoretical model of fertilization recommendation)

		Soil Test K level (ppm)						
		≤45	46-89	90-134	135-179	190-223	224-268	≥269
		K_2O to apply (kg/ha)						
Rating		*VL*	*L*	*M*	*MH*	*OP*	*H*	*VH*
Pumpkin		220	180	140	80	50	40	35
broccoli		270	200	140	90	60	40	35
onion		260	200	145	105	80	60	55
Garlic		220	150	100	55	25	10	10
leek		230	175	125	80	45	20	10
beet		280	200	130	80	40	20	10
Lettuce		225	165	115	80	60	55	45
cucumber		230	200	140	90	60	45	40
melon		240	180	130	90	60	40	30
peas		165	120	80	55	35	30	30
green bean		165	115	75	45	25	10	10
Lima-beans		150	120	90	65	50	45	40
cabbage		275	200	145	105	80	65	55
Cauliflower		280	210	155	115	85	60	55
radish		200	140	100	70	50	40	35
rutabaga		230	200	140	95	60	40	35
Carrot		225	195	150	110	80	70	60
Peppers		285	190	120	80	55	45	40
tomato		230	180	130	95	65	45	30
Eggplant		295	210	150	100	65	40	30

Fertility classes: VL: very low; L: low; M: medium; MH: medium high; OP: optimum; H: high; VH: very high

Nitrogen fertilization

One of the major challenges related to vegetable production today is the adverse environmental impacts associated with the large amounts of N fertilizer applied to these crops. Nitrogen fertilizer recovered in the above-ground plant biomass is less than 40% of the amount applied in the same year as the crop grown (Cassman et al., 2002). Nitrogen fertilizer in excess of the amount required by crops can be readily leached through soil as NO_3 and adversely impacts ground and surface waters (Hong et al., 2007). The goal of N management for crops should be to apply enough N fertilizer for the producer to receive maximum return on N fertilizer inputs without unduly increasing N losses to the environment, usually as NO_3 leaching to groundwater (Schmidt et al., 2009).

The examination of the different fertilizer recommendation guides shows the existence of three types of models of nitrogen fertilization:

1. model (I) based on the content of soil organic matter;
2. model (II) based on the nitrate content of soils;
3. Model(III) based on the addition of a single dose of N for each crop (no soil testing).

We took as reference the model III being the most widely used compared to other models, then we used the conditional expectationstatistics (EC)in order to determine nitrogen dose for different vegetables crops.

In the first step, we classified the recommended doses in descending order, and then we applied the ECto deduce the percentile ranking of the recommended fertilizer dose.The results in the table 8 showed that for example the dose of applied N to broccoli crop varied from 140kg N/ha at CE 50% to 193kg N/ha at CE 80%, this represent 38% of added N. This approach indicates that there is a large interval to find the adequate dose for this crop, in addition to this interval can be a guide for optimum fertilizer.

Table 8: Theological nitrogen fertilization dose of vegetable crops in mineral soils

Crops	**conditional expectation**		
	50%	65%	80%
	kg N ha^{-1}		
Pumpkin	100	114	118
broccoli	140	168	193
onion	112	119	133
Garlic	110	111	112
leek	112	123	129
beet	110	112	120
Lettuce	112	129	134
cucumber	114	119	123
melon	111	114	119
peas	50	56	58
green bean	45	51	62
Lima-beans	45	67	81
cabbage	140	148	174
Cauliflower	140	148	174
radish	56	60	84
rutabaga	50	50	69
Carrot	82	103	111
Peppers	129	137	140
tomato	111	134	135
Eggplant	118	143	148

II: CALIBRATION AND VALIDATION

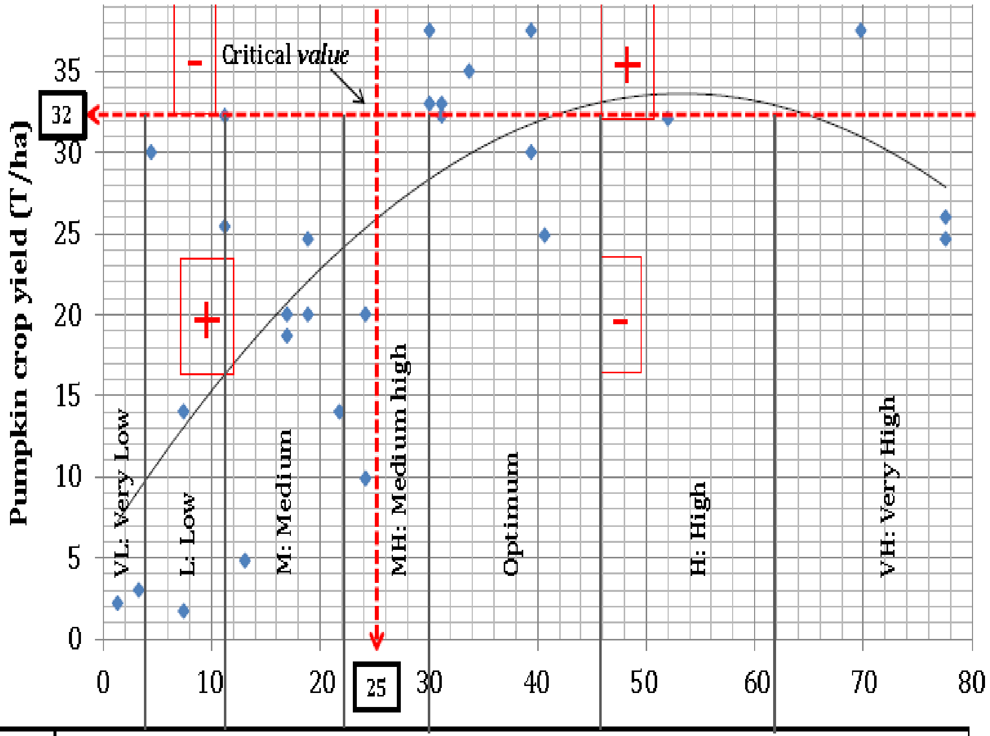
Phosphorus test calibration

The research base is developing from research projects in which measured yields are related to soil test values for the nutrient of interest and the rate of that nutrient that has been applied. Generally the pH of the Algerian soil varied from neutral to alkaline, this why we used the conversion equation of the amounts of P extracted the method MehlichIII (Mehlich, 1984) to P-Olsen. The original 27 soils sample dataset covered an extensive range of P that varied 1.4 to 76 ppm with variation coefficient of 75% (Table 1). The corresponding pumpkin harvest yield varied between 2 to 37 t/ha with variation coefficient of 49%. The difference between these variation coefficientsis due generally, that relative plant yield was better indicator of soil P availability than relative P extraction of all method of STP.TheFigure5 traduce this relation.

As showed by Figure 5 there is a good response of pumpkin crop response to the soil phosphorus fertility ($R^2 = 0.50$). The purpose of calibration of soil analysis is to determine the critical value (CV) of different major nutrients for each crop. In order to determine the critical value of pumpkin crop, we adopted *Crop Sufficiencyphilosophy,* this approach is focused the crop response to fertilization: That mean the expected response of the crop at any given soil test level is what determines the recommended level of each nutrient.

A CV for phosphorus is determined by using graphical techniques of empirical method of Cate and Nelson (1971). So the CV of pumpkin crop is 25ppm P which corresponds to 32Tha^{-1} representing 83% of maximum crop yield. According to the Cate-Nelson methods, the critical level of Olsen-P in the top 20 cm of soil was about 25 ppm: at values of greater than or equal to 25 ppm, crops achieved about 80% of their maximal yield in the absence of fertilizer application. These mean that for soil test values above this CV, there is no or less expected increase in yield when phosphate fertilizer is applied.

Below this value, some increase in yield is expecting when phosphate fertilizer is applied.



	Soil Test Phosphorus (mg/kg)						
Olsen-P(ppm)	≤ 0-4	4-14	14-22	*22-30*	30-46	46-62	≥62
Olsen-P (kg/ha)	≤0-10	10-28	28-50	50-68	68-104	104-144	≥144
	P_2O_5 to apply (kg/ha)						
Rating	*VL*	*L*	*M*	*MH*	*OP*	*H*	*VH*
Pumpkin	*220*	*180*	*140*	*110*	*70*	*40*	*30*

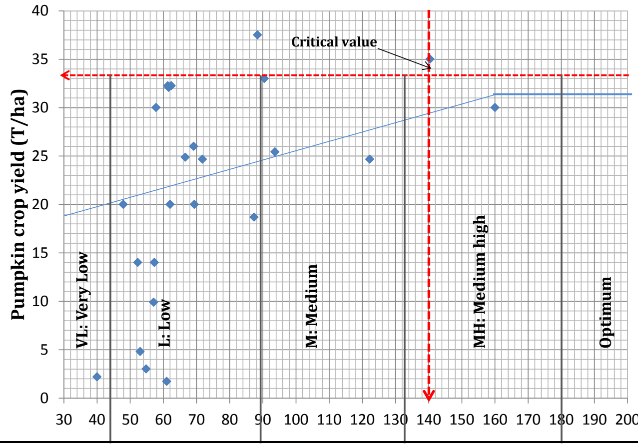
Figure 5: pumpkin crop response to different phosphorus soil fertility level

The agreement between the values of field trials and the values calculated by the theoretical recommendation fertilization guide model is generally satisfactory. Indeed, the deduced medium high fertility interval(MH) contains the obtained CV for pumpkin crop. The lower pumpkin harvest yield is associated with low P levels <25 ppm, but for practical purposes ≤20 ppm can be used to define low P soils. The middle category was associated with soil P levels between 20 to 46 ppm. Values above 46 ppm were well correlated with the highest relative yields in most fields and was selected as the level at which sufficient P is available for a good pumpkin yield.

Potassium test calibration

The 27 soil sample dataset covered an extensive range of K test soil that varied 24 to 160ppm with variation coefficient of 44% (Table 1). The corresponding pumpkin harvest yield varied between 2 to 37 t/ha with variation coefficient of 49%.

Pumpkin harvest yield responded positively and significantly to Ksoil fertility levelas showed by Figure 6, a good response of pumpkin crop response to the soil K fertility. However, the soil K fertility has not exceeded the optimum class fertility (135-179 ppm). A CV for K is determined by using graphical techniques of empirical method of Cate and Nelson (1971). So the CV of pumpkin crop is 140ppm K which corresponds to 33.5Tha^{-1} representing 90% of maximum crop yield. According to the Cate-Nelson methods, the critical level of Olsen-K in the top 20 cm of soil was about 140ppm: at values of greater than or equal to 140ppm, crops achieved about 90% of their maximal yield in the absence of fertilizer application. These mean that for soil test values above this CV, there is no or less expected increase in yield when phosphate fertilizer is applied. Below this value, some increase in yield is expected when potassium fertilizer is applied. The obtaining CV of K was more difficult and not evident because soil test K have not exceeded 160ppm, this value is included in MH class fertility, therefore the others fertility lasses (OP, H and VH) as determined by theological recommendation fertilization guide are not represented. This why More research emphasis should be spent on including sites with optimum soil K levels in order to fill a data gap.



	Soil Test K level (ppm)							
		≤45	45-89	89-134	134-179	179-223	….	≥267
	K_2O *to apply (kg/ha)*							
Rating		*VL*	*L*	*M*	*MH*	*OP*	*H*	*VH*
Pumpkin		220	180	140	80	50	40	35

Figure 6: pumpkin crop response to different potassium soil fertility level

Conclusions

Theological recommendation fertilization guide generated by using 16 international fertilizer guides show the adequacy with soil P and K test calibration. Indeed, 7 categories of soil P fertility were established: 1) Very Low (0-4ppm), Low (4-14ppm) Medium (14-22 ppm) Medium High (22-30ppm), Optimum (30-46ppm), High (46-62ppm) and Very High (>62ppm). The same K classes rating with potassium levels are generated: VL (0-45ppm), L (45-89ppm), M (89-134ppm), MH (134-179ppm), OP (179-223ppm), H (223-267ppm) and VH (>267ppm). Research is conducting to determine crop yields at different soil test levels for a given nutrient (correlation).The uses of dataset show that soil calibration generate a CV of soil test P and K of 25 and 140ppm respectively. The used*Crop Sufficiency Philosophy*method called "*fertilizing the crop*"denote more advantages than do *the maintenance approach*which emphasizes maintaining the soil fertility level at or above the point of the economic maximum yield:

1. This method is both economical and environmentally sound;
2. The only fertilizers applied will be those that increase yields, and these will be applied at optimum rates.

The next step determines how much fertilizer is required for optimum yields at different soil test levels (calibration).New field experiments are currently under way and are comparing split NPK applications vs. one full NPK application in each crop cycle in one hand, in another to determine the CV for each crop. This work will help to understand the precise N, P and K needs of vegetable and cerealcrops and the optimum economic doses for Algerian soils.

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