DISEASE RESISTANCE IN PLANTS IN RELATION TO NUTRITION BALANCE.

References relating to the paper on "Breeding for Resistance to *Piricularia oryzæ* in Rice (*O. sativa*)" by K. Ramiah and K. Ramaswami appearing in Vol. III, No. 6, Section B.

1. Konishi, S., "On Physiologic Specialisation in rice blast fungus (*Piricularia oryzæ*)," *Forsch. Geb. Pflanzenkrank* (Japan), 1933, No. 2; *Abstract Expt. St. Record*, 1935, **72**, No. 2, p. 201.
2. MacRae, W., "Blast of Paddy in Tanjore district," *Jour. Mad. Agrl. Stu. Union*, 1918, **6**, 115.
3. Neil, E. Stevens, "Suggestions for a Pan-Pacific Survey of rice diseases," *Proc. of the Fifth Pac. Sci. Cong.*, 1933, **4**, 3239.
4. Ramiah, K., "Inheritance of Flowering duration in rice," *Ind. Jour. of Agrl. Sci.*, 1933, **3**, 377.
5. Sundararaman, S., *Administration Reports of the Government Mycologist, Mad. Dept. of Agri.*, 1921-1932.
6. Suzuki, H., "On the relation of soil moisture to the development of rice blast disease, with special reference to inocular experiments on the resistant and susceptible varieties of the paddy rice and the upland rice," *Forsch. Geb. Pflanzenkrank* (Japan), 1933, No. 2; *Abstract Expt. St. Record*, 1935, **72**, 202.
7. Tadayosi, Nose, "On the Physiologic Specialisation of *Piricularia oryzæ* in Corea," *Jap. Jour. Bot.*, 1935, **7**, Abstract No. 196.
8. Thomas, K. M., "Some aspects of the control of blast disease of paddy," *Mad. Agrl. Jour.*, 1930, **18**, 596.

the parasite. Next in importance is the maintenance of characters and capacity endowed by the breeder and inherited by the plant. It is now well known that except perhaps in their fundamentals, internal and external, wide variations in the internal economy and external manifestations are possible in plants, and that in this respect nutritional factors and climatic environment play a prominent part. It is, therefore, clear that the maintenance of disease resistance characters is closely bound up with the nature

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By B. Viswa Nath,

Imperial Institute of Agricultural Research, New Delhi.

Received June 17, 1936.

I am thankful to the organisers for having invited me to contribute a paper to the symposium on "Disease resistance in plants". Although as an Agricultural Chemist I am not directly connected with the study of plant diseases, I have had occasions to investigate certain nutritional aspects of the cotton plant in relation to its resistance to stem weevil (*Pempheres affinis*) attack and of the deterioration disease of betel vine (*Piper betle*) and to gather some data on other crops. I am, therefore, glad to have this opportunity to communicate my observations on the subject under discussion.

The expression 'disease resistance in plants' brings to mind 'disease resistance in animals'. The phenomena of animal and plant resistances in relation to nutrition may not be altogether dissimilar, but the actual methods by which immunity to insect attack and disease may be conferred or their virulence may be reduced, cannot obviously be the same or similar.

The problem of resistance in plants can be considered under two main issues which are widely different. The one is inherited and the other is acquired. The first is of primary importance and is concerned with breeding varieties which are either completely immune or possess a high degree of resistance to disease. This may be due to certain morphological or anatomical features in the plant or to the presence or absence of certain substances antagonistic to, or incompatible with, the needs and habits of the parasite. Next in importance is the maintenance of characters and capacity endowed by the breeder and inherited by the plant. It is now well known that except perhaps in their fundamentals, internal and external, wide variations in the internal economy and external manifestations are possible in plants, and that in this respect nutritional factors and climatic environment play a prominent part. It is, therefore, clear that the maintenance of disease resistance characters is closely bound up with the nature and level of nutrition available and to the consequent physiological processes of the plant. This condition is expressible by the comprehensive but little understood term " Physiological balance". We are not yet in a position to define, with any pretension to accuracy, the term " physiological balance," much less to maintain it in the dynamic system of the plant in its equally dynamic substrate and environment. This is because our knowledge of plant nutrition is still very far from being perfect. It is, therefore, not surprising to find that conflicting results are often obtained by investigators. Nevertheless, the accumulation of data and lessons from failures and successes are necessary steps for the analysis of facts and the synthesis of knowledge.

Several instances are recorded in literature suggesting the relationship of such proximate constituents as nitrogenous compounds, carbohydrates, organic acids and several others found in plants, to their susceptibility or resistance to disease. The appearance or otherwise of these proximate constituents from the metabolic processes in plants is dependent on the nutrition available to the plant and the climatic factors that surround it. Thus the so-called " physiological balance " is the summation of the effects of climatic and nutritional factors. The climatic factor is as yet beyond man's control as a practical proposition and any discussion on it must still be in the realm of academic interest in so far as agriculture is concerned. The nutrition factor appears to be within human reach and with reasonably fair chances of control.

Considering nutritional factors in their ultimate aspect, it may be said that almost all chemical elements have been under investigation. From the accumulated data it is evident that most of the chemical elements can be grouped under two categories " essential " and " beneficial". The only difference is that some like manganese, boron, iodine are required in minute doses, while others like nitrogen, phosphorus, potash and calcium in large quantities. The former group of elements as also iron, magnesium and sulphur are ordinarily present in adequate quantities in the soils and fertilisers and irrigation waters and it is rarely that they require to be specially added. In this direction, therefore, ordinarily there is no risk of upsetting physiological balance in agricultural practice.

Physiological balance with reference to nutrition, restricts itself to the consideration of ratios between nitrogen, phosphorus, potassium and calcium which are added to the soil. Water being the vehicle, in which these nutrient elements are said to be conveyed from the substrata to the plant and as any defect either in water or in nutrient elements in the plant results in diminished photosynthetic activity; water balance is another important factor. Since the major elements of nutrition are capable of forming acids and bases, the *balance* in respect to these becomes in effect *acid-base-balance.* Thus the discussion on physiological balance or nutritional balance in relation to the susceptibility or resistance of plants to disease may be narrowed down into two main issues, namely, *acid-base-balance* of ash and water balance. The influence of these two factors on disease resistance manifests itself in several ways and can be measured by several standards. For purposes of this discussion, the yield of crop is taken as the standard of measurement.

I. The Resistance of Cotton Plant to Damage by Stem Weevil (Pempheres offinis) :

(*with Y. D. Wad and M. Suryanarayana*).

In this section the salient features of investigations over eight years on the factors concerned in the resistance of cotton plant to stem weevil damage are reported.

The problem is briefly this: The stem weevil lays its eggs on the hypocotyl regions of the cotton plant and covers them with a gummy secretion from its body. The egg hatches and the larva burrows into the stem. The insect feeds on the sap and soft portions of the plant, and makes in the stem irregular tunnels of all shapes and sizes. Eventually, the grub settles down to pupate and finally emerges by cutting through the bark. Although the insect exhibits a definite preference to the cotton plant as a host, it does not seem to be attracted or repulsed by individual plants in a cotton crop. So far as is known, the selective faculty of the insect is limited to the softer portions of the stem and possibly to such plants as may reasonably be expected to provide suitable nourishment to the young one. The development of the grub in the plant, and the repair of the damage caused to the plant tissues, cause a heavy drain on the plant sap. Plants that are unable to meet this drain succumb early in their career. Those that are more favourably situated strengthen themselves by developing galls round the seat of injury. Sometimes as many as half a dozen or more galls are seen on a single plant. The escape from destruction due to mechanical injury depends on the balance left over by the developing grub.

The attention of the writer was first drawn to the problem in 1923 by the Government Entomologist at Coimbatore. In a cotton crop belonging to the mills at Virudupatti nearly fifty per cent. of the plants succumbed to stem weevil attack, while in the neighbouring ryot's field there was practically no damage. The variety of cotton in both the fields was the same (Karunganni—*G. indicum*). At that time the phenomenon of attack in one field and absence in another was strongly suggestive as being due to specific substance or substances in the cotton plant which offered preferential attraction to the insect. Subsequent investigations by the Entomologist and the Cotton Specialist, Coimbatore, and my own observations have shown so far that there is nothing of the kind.

Chemical analyses of a large number of plants made in 1923 did not indicate appreciable differences in the absolute amounts of the several organic constituents of healthy and attacked plants. There were, however, significant differences in the ratio $K_2O : P_2O_5$.

$K_2O : P_2O_5$	for stem weeviled plants in manured field ..	4·96
Do.	for plants in ryot's field	9·64

This clue was followed up in the next season by carrying out analyses of individual plants from field No. 13, Central Farm, Coimbatore. The potash : phosphoric anhydride ratios were as below :

Field No. 13.	$K_2O : P_2O_5$
1. Plants attacked by stem weevil, but living with galls developed	5·56
2. Unattacked healthy plants	4·95
3. Stem weevil attacked and dead	4·50

The ratio for the plants that had the attack, but were living, is significantly higher than that for the plants that were attacked and dead.

This confirmation of the preliminary observation prompted further study. This was done in a subsequent season by submitting to individual analyses a large number of Cambodia (440) plants kindly supplied by Mr. V. Ramanathan, the Cotton Specialist, Coimbatore. The investigation was also extended to the study of the different parts of healthy and attacked cotton plants. Here again no appreciable differences were noticed in the acidic or basic constituents of the ash of healthy and attacked plants except in the case of magnesia which was consistently higher in healthy plants. The significance of this is not clear. The ratios were similar to those found previously. These are given below as excess or deficit for healthy over attacked plants.

	K_2O/P_2O_5	$K_2O + CaO + MgO/P_2O_5$
Healthy *minus* attacked : Leaf ..	+ 0·30	+ 1·69
Healthy *minus* attacked : Stem ..	− 0·62	− 3·14
Healthy *minus* attacked : Root ..	+ 0·45	+ 0·61

Assuming that normal absorption and assimilation obtains in the healthy plant, it will be noticed that in the attacked plants, there is a deficit of basic constituents in root and leaf and an excess in the stem. The pH values of the leaf and stem extracts do not, however, indicate this difference in a pronounced manner as will be seen from the figures below :

	pH Values	
	Healthy	Attacked
Stem	6·11	6·18
Leaf	5·37	5·41

If, as a result of stem weevil attack, there should be difference in the absorption and assimilation of mineral constituents by the cotton plant and if the struggle by the plant to repair damage is expressed by the nodular swelling, differences in the ratios for the stem and its gall should be visible. That it is so is seen from the figures below :

	K_2O/P_2O_5	$K_2O + CaO + MgO/P_2O_5$
Healthy stem ..	3·29	9·02
Attacked stem ..	3·91	9·62
Gall on attacked stem ..	3·58	6·48

These results suggested that by controlling ratios of the major nutrients applied to the soil, differential absorption might possibly be induced and that further indications might be secured if such plants were exposed to stem weevil attack. To this end, over a hundred large size flower pots were filled with soil and, after applying superphosphate and potassium sulphate to give different $K_2O : P_2O_5$ ratios, the pots were sown to cotton. When the seedlings were about a month old, the pots were distributed at random in a large field of cotton crop, the object being to freely expose all plants to stem weevil attack. At the end of the season counts were made with the following results :

Treatment	Percentage of plants: Healthy	Attacked and recovered	Attacked and dead
Soil alone ..	42	29	29
Soil + farmyard manure ..	35	41	24
Soil + $K_2O : P_2O_5 :: 1 : 1$ ..	10	76	14
Soil + $K_2O : P_2O_5 :: 1 : 4$ ..	12	65	23

The results of two sets of experiments on the field scale are interesting. One set of field tests was carried out in the old permanent manurial plots in which the plots received the same differential fertiliser treatment continuously for twenty years. In the second set the new permanent manurial plots were under differential feritliser treatments for only three years. The first set, therefore, approximates closely to the rigours of solution cultures without their attendant disadvantages. The second set approximates closely to fertiliser treatment under normal field conditions.

The results are given in the table below :

Treatment	Series of plots I Old Permanent Manurials				Series of plots II New Permanent Manurials			
	Attacks %	Deaths %	Exchangeable bases		Attacks %	Deaths %	Exchangeable bases	
			Total	Potassium			Total	Potassium
Unmanured ..	87 ·0	7 ·3	23 ·3	0 ·3	89 ·0	3 ·6	28 ·6	0 ·8
N + K + P ..	84 ·5	3 ·8	24 ·2	0 ·4	92 ·1	3 ·5	30 ·4	1 ·0
K + P ..	85 ·5	4 ·0	23 ·0	0 ·5	83 ·1	2 ·8	29 ·4	0 ·8
P ..	84 ·0	4 ·1	22 ·6	0 ·3	84 ·6	2 ·4	32 ·2	0 ·8
K ..	80 ·0	1 ·8	23 ·4	0 ·6	81 ·7	2 ·5	32 ·3	1 ·0
Cattle manure ..	90 ·3	2 ·1	20 ·0	0 ·4	81 ·8	0 ·9	31 ·7	1 ·2

The percentage attacks and deaths are as observed by the Government

Entomologist, Coimbatore. It will be seen that plants under all treatments were attacked by the stem weevil. This lends support to the view previously expressed, *viz.*, that the stem weevil visits all plants indiscriminately. Deaths are proportionately very small and the differences are too small to justify serious consideration. It was unfortunate that the experiments could not be repeated in another year. However, the indications are generally in agreement with the previous discussion on balance and ratios. Particularly is this more in evidence in series II than in series I. In the latter series the differential treatments continued over a long series of years and the effects are, therefore, of an emphasised nature and consequently in this set of plots the balance was, perhaps, in an unstable equilibrium. An interesting observation is the effect of cattle manure in series II. The attacks and deaths were low and the values for exchangeable bases were as good, if not better than, when artificial fertilisers were applied. For a field experiment in the tropics and a crop like cotton whose water balance is delicately poised, the agreement between laboratory results and field behaviour appears to be good. The results with cattle manure as a factor in maintaining nutritional and water balance are suggestive.

The analyses of another crop in series I plots show a general relationship between manurial treatment and leaf composition. The deficiency in N, P and K in the soil is reflected by a decreased content of that element in the leaf, but a constancy in the ratios of nutrients was evident throughout the growth period of the plant. The magnitude of the ratios, however, varied with the nature of the fertiliser treatment given to the soil.

II. Betel Vine Investigation:

(with T. Lakshman Rao and M. R. Balakrishnan).

The problem in regard to betel vine was this. In the betel vine areas of the Noyel valley in the Coimbatore district there had been a gradual and general deterioration in the growth and yield of vines. The production of the leaves was reduced, their size became smaller and the side branches became fewer and lankier. The area was situated in a low level and the soil was in a state of supersaturation with water for about eight months in the year. The conditions of betel vine cultivation are such, that high humidity in the interior of the crop was a feature. Root Knot eel worm—*Caconema (Heterodera) radicicola* and among several fungi, a pathogenic fungus *Rhizoctonia*, which caused blackening of the stem at about a foot from the ground level and then death, were noted. At first it almost looked that the eel worm and the fungus were responsible for the damage. In a co-operative investigation for five years by the Chemist, Entomologist and Mycologist, it was conclusively proved that the diseased condition of the betel vine crop was due mainly to bad soil conditions and that all external manifestations of disease attributed to earth worms, presence of pathogenic fungus were but an index of unhealthy soil conditions. The betterment in soil conditions improved the yield to nearly normal.

The point of interest for purposes of the present discussion lies in the effect on water balance in the plant. The water balance in the soil was reflected in that of the plant and also in its mineral composition as can be seen from the following analyses of healthy and diseased plants:

Composition of ash of leaves.

	Composite sample from all plots		Sample from plots	
	Healthy	Diseased	Best situated	Worst situated
	%	%	%	%
$Fe_2O_3 + Al_2O_3$ ..	0·66	0·44	0·95	0·68
CaO ..	1·82	2·02	0·95	0·55
MgO ..	1·32	1·79	1·28	0·74
K_2O ..	5·13	3·83	5·83	2·70
P_2O_5 ..	0·66	0·55	0·65	0·42

The water content of leaves as determined by drying them at 100° C. and their nitrogen contents were higher for leaves from healthy plants than from diseased plants.

Sample	% Water content in leaf		% Nitrogen content in leaf	
	Healthy	Diseased	Healthy	Diseased
From all plots in September ..	84·04	76·64	3·04	1·75
Plot 3, October ..	79·26	76·60	2·64	2·32
Plot 4, October ..	83·52	76·21	2·74	2·40
Plot 3, November ..	81·33	79·17	2·53	2·38
Plot 4, November ..	85·60	72·50	2·78	2·63

It would appear that the state of soil-water relationship affected the water balance in the plant. It is difficult to say whether the absolute water content in the diseased leaves was definitely low or whether the water existed in a "*bound*" state and could not be removed at 100° C. The lower nitrogen content of the diseased leaves does not suggest a relatively higher content of colloid material which would be expected to imbibe and "bind" water. The existence of hydrophilous carbohydrates might be equally responsible. In any case, the interesting and instructive point that has emerged from the available data is that the effect on the plant of supersaturated condition of the substrate in regard to water, is not merely defective root aeration, but to induce defective water balance in the leaf to the detriment of the general health of the plant.

III. Abnormal Leaf Fall of Rubber Trees.

In this Section are recorded the results of periodical analyses of rubber tree leaves relating to normal and abnormal leaf-fall. The data reported do not belong to any specific investigation by the author, but refer to the analytical work done, as Agricultural Chemist, Coimbatore, on samples sent in by Mr. D. G. Munro, the then Deputy Director of Agriculture, for planting districts. The data are presented here on account of their interest in respect to the potash content of the leaves.

Percentage of potash on ash of leaves for six trees in one season.

Particulars	Normal leaf-fall leaves	Abnormal leaf-fall leaves
Tree 1	10·61	20·70
Tree 2	5·32	21·29
Tree 3	8·58	21·03
Tree 4	11·26	26·76
Tree 5	13·61	23·15
Tree 6	14·40	25·17

Periodical collection during season 1924–25.
(Mooply Experiment Station. Average for 6 trees.)

Normal fall leaves		Abnormal fall leaves	
% K_2O on		% K_2O on	
Leaf	Ash	Leaf	Ash
0·9	12·1	1·7	25·4
1·1	12·6	1·7	19·0
0·9	10·9	1·5	25·2
		1·5	22·9
		1·6	19·7

The leaves were from the same trees. Those relating to abnormal leaf-fall had an infestation of phytophthora fungus. The association of abnormal leaf-fall and fungus with a consistently higher concentration in the leaf is the opposite of what has been seen in the case of betel leaf. This is suggestive that potash should not always be considered as an antidote for disease.

IV. General Discussion.

It is evident from the foregoing that, genetic constitution apart, the susceptibility or resistance to disease and insect attack is governed by the internal condition of the host plant and that nutritional and water balance play a prominent part. Lees[1] has cited several instances to show the varying susceptibility of plants to disease and insect attack, due to the influence of soil conditions and growth of the plant. McRae and Shaw[2] at Pusa have shown that the incidence of wilt (*Fusarium vasinfectum*) of *Cajanus* with the type of manurial treatment. According to them, manuring with superphosphate or cattle manure increased wilt. A green manure like sann hemp reduced wilt affection, while the addition of phosphate with the green manure increased it. The effect of phosphate might be the disturbance of acid-base ratio. Wallace[3] concludes that leaf scorch in apple trees arises generally from defective nutrition, but that in many cases it develops as the result of unsatisfactory conditions of water-supply within the plant. Grubb[4] discusses the effect of potash fertilisers upon apple trees as being able to prevent the development of leaf scorch.

The study of the influence of manures and fertilisers on acid-base balance in plant ash and on water balance within the plant may not only explain how substances like potash salts prevent or moderate damage from disease, but would also enlarge our knowledge on this aspect of disease resistance in plants. Fertiliser salts exercise only a very limited action on the pH of the plant juice but considerably influences its buffer capacity, and also affect the acid-base balance of plant ash. It would appear that fertiliser salts can also influence the state of water balance in the plant by altering the proportion of bound water and the hydration or dehydration capacity of the tissues.

REFERENCES.

1. Lees, *Annas. App. Biol.*, 12.
2. McRae and Shaw, *I. C. A. R.*, Monograph No. 7.
3. Wallace, *Jour. Pomol.*, 7.
4. Grubb, *Jour. Pomol.*, 7.