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CONTENTS

1

RELATIVE DROUGHT RESISTANCE OF SOME CROP PLANTS

By

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INTRODUCTION

The severe drought of 1895 and the disastrous harvest of 1921 in Russia caused a national calamity. Wheat yield was reduced by about 75,00,00,00 bu. in Canada during 1930-34. The recurrence of this natural calamity in our country in past up-set the Governmental plans to make it self-sufficient to feed its population. Breeding and selection of drought resistant variety, inducing resistance to drought and study of the basis of drought resistance are some of the major problems needing investigation in this connection. The present contribution on the relative drought resistance of wheat Pb. 591, wheat Agra Local and barley C. 251-the major crops of the tract-aims towards part fulfilment of such needs.

HISTORICAL

Aamodt and Johnston (1936), Kenway *et. al.* (1942) and Platt and Darroch (1942) observed varietal differences in the drought resistance of plants; however, Ashby and May (1941) considered that the superior drought resistance of Algerian Oat to Fulghum was due to its earlier physiological maturity. Whiteside (1941) found little difference in the drought resistance of wheat varieties when plants were grown from vernalized seeds (presumably to equalise the length of the life cycle).

Seedling and pre-flowering stages have long been recognised as critical stages (Singh *et. al.* 1935) while embryonic and tillering stages as highly resistant to drought (Chinoy 1947). Milthorpe (1950) could not find varietal differences in the drought resistance of wheats at the early seedling stage.

It is thus apparent that drought resistance of plants is influenced by their early or late flowering behaviour and the stage of development.

TECHNIQUE

The experiment was conducted at B. R. College, Agra, during 1954-55 (to confirm certain aspects of the earlier (1947-51) work but slightly on an altered lay-out). Plants were raised in earthen pots. Soil, obtained from an uncultivated patch of farm land, was mixed with Municipal compost in the ratio of 2 : 1. The initial soil moisture at sowing, which commenced on November 11, 1954 was 15·5% on fresh weight basis. 4-5 plants were allowed to grow in each pot and 6 replications maintained.

Pots were grouped into four sets. One of these was watered normally while the remaining ones were droughted at different developmental stages. The complication due to varying degree of earliness in flowering was largely eliminated by introducing soil drought at similar stages of development *viz*; tillering, shooting and flowering. When plants reached the desired stage water supply was with-held from them, and they were allowed to wilt permanently for 4-5 days. The attainment of permanent wilting was judged by visually noting the rolling and turgor of leaves in morning commencing from the first drooping stage. Soil moisture was determined at the beginning and at the end of each drought period. Intensity of soil drought, which is given in table 1, was calculated by dividing the period of drought by the mean soil moisture. Data on growth, development and on yield were recorded and statistically analysed. Resistance index was calculated by dividing the values under different drought treatments by those under full watering. The higher indices were taken as a critierion of greater drought resistance.

TABLE 1.

Intensity of soil drought in pots (average of six replicates)

Tillering stage.			Shooting stage.			Flowering stage.		
*C.	L.	B.	C.	L.	B.	C.	L.	B.
3.52	3.63	3.59	4.08	3.98	4.00	3.28	3.20	3.17

* C=wheat Pb. 591, L=Wheat Agra Local; B=barley C. 251.
The same is followed in tables 2 and 3.

RESULT

The result is summarised in tables 2 and 3. Mean relative growth rate of height and dry weight, average number of tiller and leaf, flowering processes and observations at harvest are presented in table 2. From the statistical analysis the effect of crop and of water supply has been brought out. The interaction (crop X water supply) is represented here as the resistance index (table 3).

TABLE 2.

Character.	Crop differences				Effect of water supply				
	C	L	B	C. D.	*N	T	S	F	C. D.
				Mean relative growth rate					
Height	0.03760	0.03638	0.03503	0 00016 0.00061	0.03754	0.03769	0.03386	0.03693	0.00054 0.00072
Dry Woight	0.04148	0.04117	0.03979	0.00034 0.00045	0.04141	0.04178	0 03903	0.04100	0.00040 0.00053
				Average number of tiller and leaf					
Tiller	6.27	8.58	9.28	0.11 0 14	8.41	7.52	8.21	—	0.11 0.14
Leaf.	32.21	41.21	45.22	0.53 0.70	41.40	39.00	38.37	—	0 53 0.70
				Average time (days after sowing) taken by plants to attain flowering.					
Sheath opening	101.10	96.70	92.10	0 91 1 22	90.80	98.20	100 90	—	0 91 1.22
Flower ing	107.90	101.80	96 00	0.77 1 03	97.21	102.97	105.14	—	0.77 1.03
				Observations at harvest					
Total† florets.	65.00	69.30	57.00	1 46 1.95	64.80	65.00	61.50	—	1 46 1.95
Fertile† florets.	52.00	53.80	49.40	0.96 1.28	58.33	58.33	49 33	40.83	1 12 1.49
Grain† Number	49.88	47 12	46 31	0.58 0.77	54.08	54.17	45.25	37.58	0.66 0.88
100-Grain Weight‡	3 74	3.30	3.60	0 13 0.17	3.03	3 17	2.76	1.68	0 15 0.19
Grain yield‡	5 35	5 01	5 03	0 26 0.35	6.03	6 34	4.91	3 20	0 30 0.40
'Bhusa' Yield‡	11.98	11.60	8 91	0 60 0.80	11.32	12.18	9.01	10.80	0 70 0.93

* N = normal water supply; T = drought at tillering; S = drought at shooting; F = drought at flowering; C. D. = critical difference The same is followed in table 3.

† in the main-shoot ear; ‡ gms. per plant.

TABLE 3.

Resistance index in plants

Crop.	Water supply N.	T.	S.	F.	Crop.	Water supply N.	T.	S.	F.
		Height					**Dry Weight**		
C.	1.000	0.996	0.660	0 922	C.	1.000	1 047	0.679	0.919
L.	1.000	1.002	0.660	0 925	L.	1.000	1.045	0 680	0.915
B.	1.000	1 005	0.769	0 950	B.	1.000	1.050	0 755	0.940
		Tiller					**Leaf**		
C.	1.000	1.038	0.963	—	C.	1 000	1.046	0.954	—
L.	1.000	1.040	0 961	—	L.	1.000	1.042	0.954	—
B.	1.000	1.040	0.975	—	B.	1.000	1.048	0 970	—
		Total florets					**Fertile florets**		
C.	1.000	1.008	0.947	—	C.	1 000	1.008	0 824	0.664
L.	1.000	1.000	0.950	—	L.	1.000	1 000	0.829	0.667
B.	1.000	1.000	0 948	—	B.	1.000	0 991	0.889	0.778
		Grain number					**100—Grain weight**		
C.	1.000	1.000	0.821	0.664	C.	1.000	1.051	0.900	0.520
L.	1.000	1.005	0.819	0.667	L.	1.000	1.047	0.903	0.526
B.	1.000	1.000	0.873	0.759	B.	1.000	1.045	0.935	0.623
		Grain yield					**"Bhusa" yield**		
C.	1.000	1,045	0.788	0 500	C.	1.000	1.075	0 776	0.948
L.	1.000	1 048	0 790	0.500	L.	1.000	1.075	0 776	0.947
B.	1.000	1,049	0.859	0.591	B.	1 000	1.078	0.850	0.970

The data presented here show that the mean relative growth rate of height and dry weight was significantly greater in the wheats than in barley, and that between the wheat varieties the same was greater in Pb. 591. Drought at the tillering stage increased the growth rate while the same at the shooting and flowering decreased it; the effect of the later two was significant.

Average number of tiller and leaf was greater in barley than in the wheats, and greater in Agra Local than in Pb. 591. These differences were highty significant. The depressive effect of shooting drought was significant. The similar effect of drought at the tillering stage was because of the averaging of the entire data collected on the successive sampling dates including the final ones showing enhancing effect.

Barley flowered significantly earlier than the wheats and between the two wheats Agra Local did so earlier than Pb. 591. Flowering processes were significantly delayed as a result of wilting, more so at the shooting stage apparently because of its late occurence.

In general, barley produced fewer florets and grains in the main shoot-ear, and gave lower yield of grain and "Bhusa" than the wheats. Between the two wheat varieties Pb. 591 had more grains, and gave higher yield of grain and "Bhusa" than Agra Local although it had fewer number of florets. The test weight was of the highest order in Pb. 591 followed by barley and Agra Local. Drought at the tillering stage had enhancing effect on all these characters while the same at the shooting or flowering had adverse. The degree of the effect and the levels of significance can be clearly visualised in table 1.

Since the formation of tillers, leaves and total florets was almost complete before flowering, the question of observing the effect of drought at this stage did not arise.

DISCUSSION

The consistently higher resistance indices in barley as compared to those in the wheats (table 3) indicated higher degree of resistance to drought in this crop. A high positive correlation between greater drought resistance and greater xeromorphism has been reported earlier in this crop (Singh 1954, 1955). Data on water requirement indicated greater tendency to economice the expenditure of water under drought conditions on the part of barley (communicated to Rajputana University Studies 1957). Results of cryoscopic and Calorimetric determinations have also shown higher osmotic pressure and bound water in barley than in the wheats (to be communicated else-where). It may be added that higher osmotic pressure and bound water restrict the with-drawal of water from cells under the stress of wilting. The two wheat varieties had almost identical resistance indices (table 3) showing equal degree of drought resistance. This is further supported by the absence of a positive correlation between greater drought resistance on the one hand and greater osmotic pressure, bound water, greater tendency to reduce water requirement and greater xeromorphic features on the other as stated above for barley.

Plants at the tillering stage were manifest with higher resistance to drought while the same at shooting or flowering with lower as judged by the higher or lower indices at the corresponding stage. Plants were the most susceptible to drought at the shooting stage with regard to height, dry weight and yield of "Bhusa" only (table 3), obviously because of the enormous increase in height and size of plants during the shooting period. Drought at flowering proved more damaging to characters *viz;* fertile florets, number and quality of grains and grain yield, which were studied after the flowering stage. Injurious effects of wilting are supposed to accrue to plants through the increase in cell viscosity, loss in the assimilatory activity, retardation of translocation, increase in hydrolysis over synthesis and suppression of cell formation and enlargment. The greater proportion of meristematic to vacuolated cells at the tillering stage is probably the cause for the greater resistance to wilting at this stage. It may be added that meristematic cells have relatively more bound water and less free water. Drought alternating with irrigation probably stimulates the meristematic cells to rapid cell division and therefore, enhances development.

Since plants were droughted at their own developmental stages to eliminate the complications due to early or late flowering behaviour of crops, and the intensity of soil drought was almost the same in each case (table 1), the observed differences between wheat and barley are probably inherent. Since the weather conditions could not be indentical even for the same stage of development of the crops as the drougt periods never coincided, it is apparent that more definite conclusions can be drawn only if the life cycle of plants is equalised by photoperiodic and vernalization treatments, and the experiments are conducted under strictly controlled conditions of humidity and temperature.

SUMMARY

The relative drought resistance of three crops *viz;* wheat Pb. 591, wheat Agra Local and barley C. 251 was investigated at B. R. College, Agra during 1954-55. Plants were grown in earthen pots under normal water supply. Drought resistance was judged by introducing soil drought at tillering, shooting and flowering stages, wilting the plants permanently for 4-5 days, and by studying their growth, development and yield in relation to normally

watered plants. Separate sets of pots were kept for each drought treatment. The complication due to early or late flowering behaviour of crops was largely eliminated by droughting the plants at their own developmental stages. Resistance indices were calculated by dividing the values under drought conditions by those under full watering.

Based on resistance indices, barley was observed to be more drought resistant than the wheats. The wheat varietes appeared to have almost equal degree of drought resistance. Drought at the tillering stage enhanced the growth, development and yield of plants while the same at the shooting and flowering adversely affected them, the last affecting the grain particularly.

ACKNOWLEDGEMENTS

Thanks are due to Dr. J. J. Chinoy, Reader in Botany, Delhi University for his valuable suggestions on different aspects of the work, and to Dr. Bahadur Singh, Professor of Botany, B. R. College, Agra, for extending facilities for the work.

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2

NATURE AND NURTURE

(Popular University Extension Lecture Delivered)

At

M. S. J. College, Bharatpur, 8th January 1957.

By

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Jaswant College, Jodhpur.

INTRODUCTION

India has achieved her independence and the Indian Nation is on the march. We are on the threshold of national reconstruction, the mighty river valley schemes have significantly added towards our agricultural production as a result of the completion of our first five year plan. What is the role of the botanist or the agriculturist ? Whether it is the Nature or the Nurture that is responsible for an increased yield of crops in the field. The purpose of my talk this afternoon is to show that Nature is more important than Nurture; in other words it is the Heredity and not the Environment. The correct answer, however, is that both are necessary.

If you possess an ordinary cow, the quality and yield of milk will also be poor and small; but if you feed her well, keep her in good surroundings, milk her at fixed hours thrice and take good care of her, you can increase the yield but a limit will soon be reached beyond which it will become difficult to further the milk yield or improve the quality and yet if you want better and more milk, you will have to change the cow for a better breed. Same holds good for plants. By giving good manure, proper water supply, sufficient light and air and protecting the crop from insects, fungi, bacteria and virus diseases, you can manage to have the best results. A plant of *Chrysanthemum* can be made to prouduce a flower as big as a dinner plate or a shrub with numerous small flowers or a cascade by special care and prunning. Similarly large and beautiful flowers are produced under glass-house conditions. A wild rose with only five petals to-day exhibits remarkable varieties of shades and fragrance with multiplicity of its corolla; but when left to Nature these glass house plants or the rose will produce only ordinary individuals. In a country like India with a underdeveloped system of agriculture, a crop depending upon rain water and poor natural soil shows a spectacular result like the yield of rice; the average yield per acre in India is about 800 lbs. but in a State like Travancore having more favourable climate, proper irrigation and manuring facilities, the yield increases upto 3000 lbs. per acre.

ACQUIRED CHARACTERS

This and such other observation of the effects of environments on organisms makes man a wistful thinker and he imagines that all his good qualities and achievements of his life time will be transmitted to his children; but it is not so; it is a myth. The girls born particularly in aristocratic families in China are given wooden shoes; for small feet of women in China are considered a beauty but no woman in China has produced a progeny of girls with natural small feet. Same has been proved by experiments on rats; thousands of generations have been bred after cutting off the tails of each progeny; but never we have obtained rats without tails in any succeeding generation. It is fortunate, therefore, that if we cannot transmit good characters acquired in our life time to our children, we cannot transmit bad traits either. We see that by environmental manipulations, improvements can be brought about but there is an upper limit to this improvement and there exits a definite contingency of reversion to the original and natural state of affairs in the succeeding generations. What are then the methods that will give results of permanent nature ? The chief of these is the genetical improvement of the organism.

SELECTION

Since ancient times, the method of selection in the improvement of our crops is well known. By selecting best plants from the field and continuing the process year after year, considerable improvement can be brought about in the yield of the crop. The propagating organs like seeds, bulbs, tubers or any other parts of the plant are selected from the best specimens for this purpose. It is possible, in view of our present knowledge of this phenomenon of selection, to isolate pure lines giving high yields by self pollination and careful selection.

To say that Beet root contains sugar was an idea ridiculed in the olden times; but to-day the Beet root has been improved so much by selection that it is a serious rival of the sugarcane. In the native forests the Brazilean Para Rubber tree yields only 25 30 lbs. of rubber; selected clones in Malaya yield 400 lbs. and under experimental conditions, it is possible to get as much as 2000 lbs. of rubber per acre.

HYBRIDIZATION

Another method for improving the nature of organisms is Hybridization. Marvelous results have been obtained in India and elsewhere in the world as a result of careful breeding by crossing of varieties of different plants; for example the quality of sugar-cane has been improved in Java and India; not only the sugar yield but the ability of hybrids to resistance to disease and unfavourable conditions has been improved from crossings of the wild cane known as 'KANS' (*Saccharum spontaneum*). Another notable example is the wheat which has been improved in various directions—higher yield and resistance to rust disease; in fact some varieties have been produced in Rajasthan and are successfully grown in the local climate. A cross between wheat and rye promises good results in combining the many good qualities of wheat and the resistance to cold of the rye. Similar results have been obtained in the improvement of Maize, Linseed, Cotton, Chillies etc. in India.

It will be appropriate here to mention a great name in Science in this connection. It is that of Gregor Mendel, an Austrian monk who carried out hybridization experiments on Sweet Pea as a hobby and was the first to discover the most fundamental law in genetics, 'the law of Segregation.' It became possible to arrive at this and other great generalizations because of his careful and accurate statistical records of all his experiments. These discoveries of Mendel, far ahead of the times in which he lived (1865), remained obscure and unappreciated till 1900 when three other botanists Tschermark, Correns and De Vries working independently rediscovered them in Germany, Austria and Holland.

An American Scientist T. H. Morgan working on the fruit fly *Drosophila* made very notable further contributions to the study of genetics, discovered the great Laws of Linkage and placed the modern science of genetics on a solid foundation. His work won for him the Nobel Laureate. We cannot forget the debt we owe to the great Russian plant breeder and geneticist N. I. Vavilov who sent out great many expeditions to Central Asia for collecting wild varieties of cultivated plants for his hybridization experiments; as a result of his researches great improvements were brought about in wheat and potato.

MUTATION

In nature changes are sometimes brought about suddenly and by chance. Hugo De Vries, the famous Dutch botanist one day observed in his botanical garden at Utrecht that among his crop of prim roses and shirly poppies there were some plants looking entirely different from the rest. Not only this but he found later by continued observation on those new individuals that they maintained their newness in succeeding generations. This gave him a new idea of Evolution by means of Mutation rather than through small continuous variations seen in the organisms. The latter was thought to be the basic principle in the theory of Evolution as advanced by Charles Darwin.

It is now known that these sudden and chance variations of big type known as mutations are really due to constitutional changes in the nucleus of the cell. If you examine a small bit of plant or animal tissue under a microscope, you will see a dark circular body like the pin-head in the centre of each cell. This is the nucleus and is the physical basis carrying all the traits of the organism; in reality the nucleus has a very complicated structure, made up of numerous rod like bodies (chromosomes) on which are seated as if still smaller bits of living matter carrying singly or in groups the characteristic features of the organism such as tallness or dwarfness; smoothness or wrinkledness; black or blue colour of the eyes; maleness or femaleness etc.

These living bodies forming the most important parts of the nucleus are usually very stable things and keep the organism in a delicately balance state; but sometimes though rarely this balance is upset in nature and mutations result. It has been seen that generally these mutants are harmful and end only in producing ugly monstrocities; but sometimes Nature does produce useful mutants which are also known as "bud sports". A flower like the

Chrysanthemum has given rise to many "bud sports" which are seen as novelties in a garden. Among the economically important plants is the Washington navel orange. An American tourist brought a branch of this seedless variety of orange from South America where it was first discovered and propogated it by vegetative means in California, giving rise to the famous Orange Industry in that country. Similar is the origin of Emperor seedless grapes which arose as a bud sport from a seeded variety. The wild cabbage of the coastal regions of Europe and Africa has given rise to many varieties of Cauliflowers etc. in the manner of "bud sports".

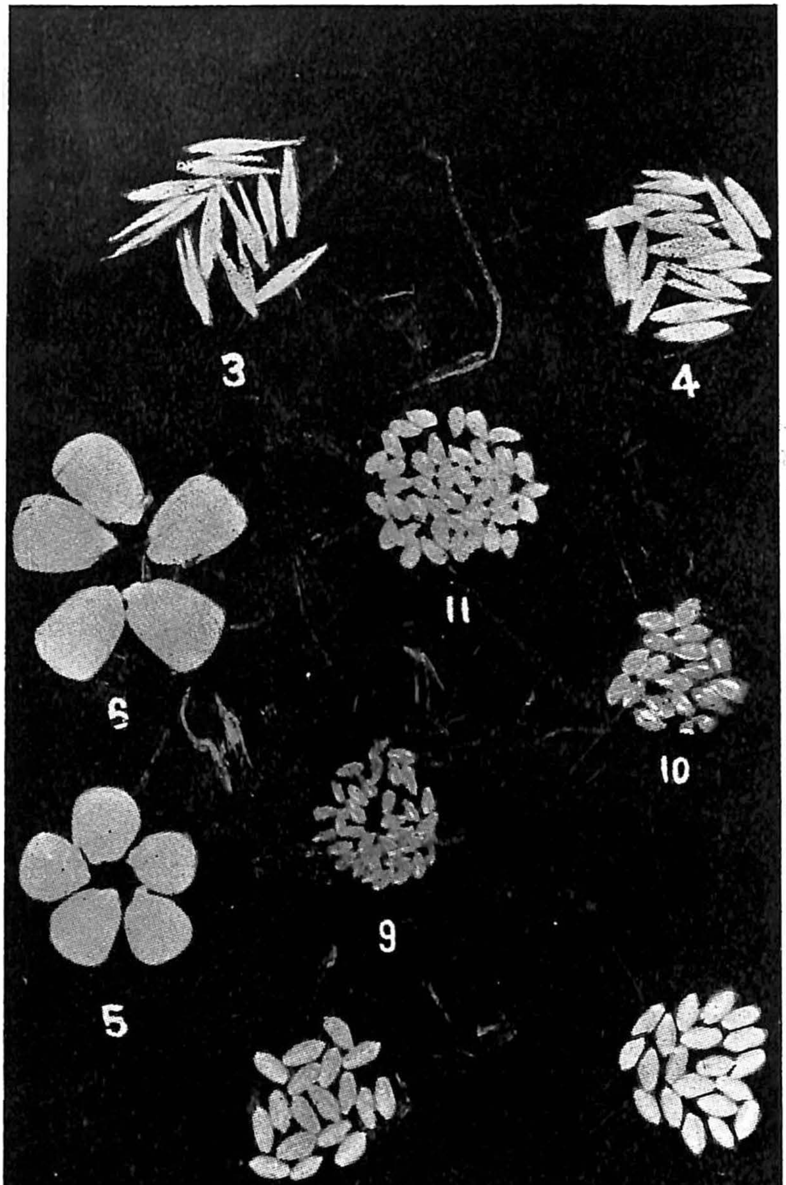
As remarked already that these "bud sports" or mutants are sudden and chance products and one had to wait patiently for these chances to appear in nature, for the simple reason that the genes (units of the chromosomes carrying singly or in groups characters of the organism) are very stable substances. However, H. J. Muller another great figure in the field of science of genetics and a Nobel Laureate, carried out experiments by exposing these genes to X-rays, ultraviolet rays, temperature shocks etc. and found that the rate of mutation in the genes can be altered. This opened up a new field of research with great future possibilities. For instance as a result of this study the blue mould *(Penecillium notatum)*, our source of the wonder drug Penecillin, has been made to produce new mutants capable of giving higher yield of the medicine. There is no doubt that effects of radiation in the field of genetics open up new vistas of investigation and research.

CONCLUSION

Reverting back to the question Nature or Nurture, it can be safely asserted that time care and money spent on an inferior plant or animal will be better utilised if an organism of a superior quality is taken in the beginning for it is bound to give better dividends. The relative role of heredity and environment can be summed up in the words of Goldscmidt. "One hears frequently that the organism is the produt of heredity and envoronment. I cannot agree with it. Environment can affect the organism only within limits set by its hereditory constitution. Beyond there is no reaction or no organsim. Thus after all it is the heredity that makes the organism".

EXPLANATION OF FIGURES

Figs. 1 & 2.	Improved breeds of a cow and a bull.
Figs. 3 & 4.	Oats, N. P. 2 & improved hybrid N. P. 3 respectively.
Figs. 5 & 6.	Maize, Malan White and improved hybrid GA xx 35.
Figs. 7 & 8.	Wheat, common variety and improved N. P. 719.
Figs. 9, 10 & 11.	Linseed, N. P. 12 & improved hybrid N. P. R .R. 9 and N. P., R. R. 439.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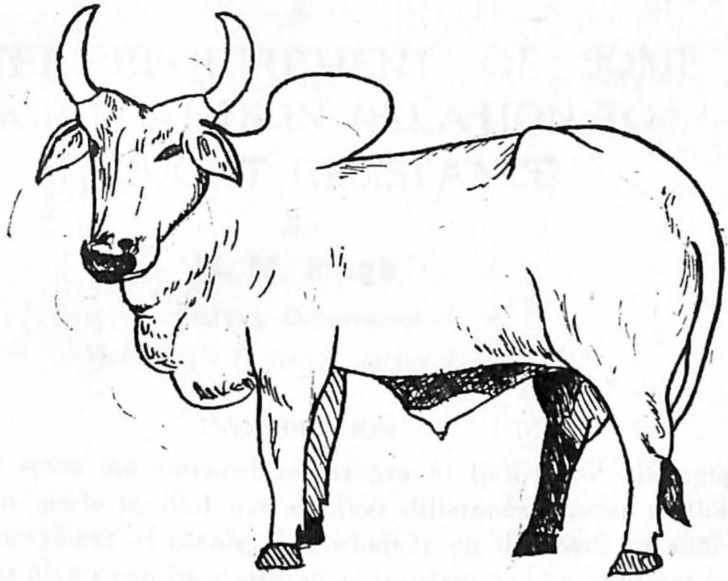
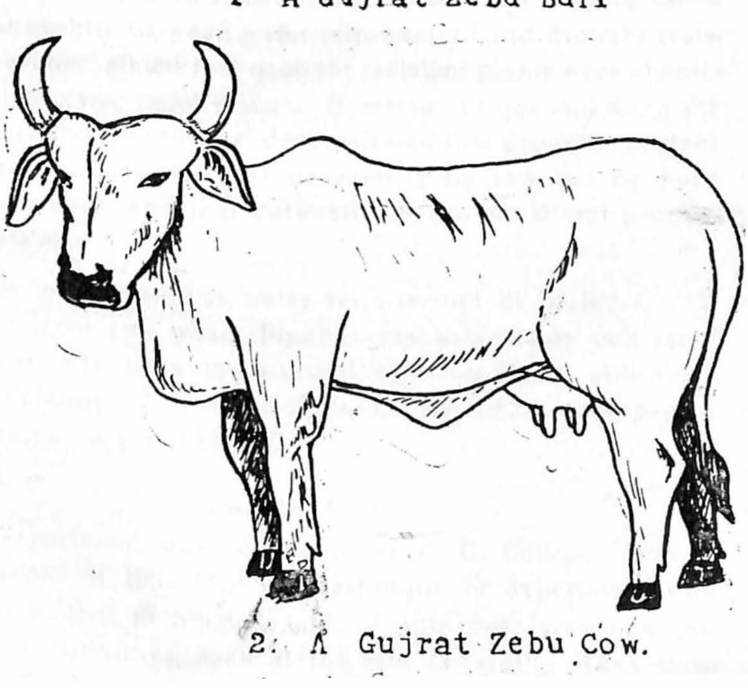
PLATE, 1.



1 A Gujrat Zebu Bull



2. A Gujrat Zebu Cow.

3

WATER REQUIREMENT OF SOME CROP PLANTS IN RELATION TO DROUGHT RESISTANCE

By

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INTRODUCTION

Ever since the classical researches of Hellriegel[3] attempts have been made to find out whether differences occur in the water requirement of plants, and whether on the basis of such differences plants can be classified as resistant or non-resistant to drought. Earlier opinion seems to be focussed on finding out a direct relationship between water requirement and drought resistance. Schroder[7] stated that drought resistant plants were characterized by low water requirement. However, Briggs and Shants[1,2] and Maximov and Alexandrov[5] demonstrated that drought resistant plants were characterized not necessarily by low but by high water requirement, and that between the two no direct proportionality existed.

In the present studies water requirement of barley C 251, wheat Agra local and wheat Pb.591—the extensively cultivated winter crops, has been investigated, and correlated with their drought resistance. This series of experiment forms an appendix to the previous work of 1948-50.

TECHNIQUE

The experiment was conducted at B. R. College, Agra in the 'rabi' season of 1954-55. The technique of experimentation was similar to that of Singh *et. al.*[8]. Plants were grown in galvanized iron containers, each of the size 11″×11″. They were filled with 21 lbs. of the soil-mixture prepared from Municipal compost and the soil obtained from an uncultivated patch of lower under deficient. In the experiments on the relative drought resistance[9] of the crops barley has been observed to be more drought resistant than the wheats. When these two findings are correlated it appears that the more drought resistant plants spend water liberally when it's supply is plentiful but economise it's expenditure when the supply is limited. However, Schroder[8] stated that lower water requirement was an indication of greater drought resistance. He arrived at the conclusion from his work on millets and cereals. The crops of these two groups are grown in two different seasons, and unless they are grown in one season their water requirement and drought resistance should not justifiably be compared.

Such a correlation between water requirement and drought resistance is not evident between the two wheat varieties *viz.*, Agra Local and Pb.591. In the first place the two wheats have shown almost the the same degree of drought tolerance[9]; secondly Agra Local has higher water requirement than Pb.591 under both the optimum and deficient water supply as is apparent from the present investigations.

CONCLUSION

Under normal water supply the more drought resistant plants have higher water requirement; under restricted water supply they are, however, more economical. Soil drought reduces the transpiration and water requirement of plants.

ACKNOLEDGEMENTS

The author is grateful to Dr. Bahadur Singh Professor of Botany B. R. College, Agra, for extending facilities for the work.

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4

GROWTH AND YIELD OF SORGHUM AS AFFECTED BY TREATMENT WITH IAA AND NoXA

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Introduction

The authors present in this article the results of some studies on the effect of treating *Sorghum* plants with aqueous solutions of 3-Indolylacetic acid (IAA) and β-Naphthoxyacetic acid (NoXA). The application of the various auxins has been found to produce varying results on the different plants and investigations have to be conducted to determine which auxin suits a crop plant best, at which concentration, applied at what all stages during the life cycle and under differing conditions of growth. Very little work has been done on the effect of such substances on the production of grains and straw on the crops grown under the conditions obtaining in Rajasthan, where both grains and straw are important in its economy.

Material and Methods

Healthy seeds of *Sorghum*, variety H.473, were used for these studies. They were divided into three lots. One lot was soaked for 24 hours in aqueous solutions of 50 parts per million (ppm) concentration of IAA and NoXA and then sown in pots and treated with the auxins during the vegetative period by applying them to the soil at 5 *ccs* per plant at weekly intervals. These are referred to as the 'pre-treatments'. The second lot was soaked in distilled water for 24 hours, sown in pots and the plants treated with the acids during the vegetative phase by application to the soil as above. These are referred to as 'post-treatments'. The third set was also soaked in distilled water and the plants grown as 'control' without any treatments being given.

After soaking in distilled water or the auxin solutions as the case may be, the seeds were sown in earthernware pots of size 8″ × 8″ which were filled with garden soil mixed with cowdung in the proportion of 3 : 1, because the soil here is lacking in organic matter. To each pot was added ½ oz of ammonium sulphate and superphosphate. Potassic manure was not added because the soil here is rich in this element and needs no supplementation. The pots were placed in a glass house. After the first fortnight the plants were thinned down in each pot to five and two pots with ten plants were maintained under each treatment. Once a week fresh applications of the acids at the same concentration of 50 ppm were made to the soil at 5 *ccs* per plant as mentioned already, till the plants flowered. During the growth of the plants manures were applied once a month at 4 ozs. of cowdung and ½ oz each of ammonium sulphate and superphosphate per pot so that nutritional factors may not be limiting. The meteorological conditions obtaining during the growth period of the plants were :—

Max. Temp. varied from 88.6°F in Oct. 1954 to 71°F in Jan. 1955 and 89°F in March 1955.

Min. Temp. varied from 58.9°F in Oct. 1954 to 41.7°F in Dec. 1954 and 58°F in March 1955.

Rel. Humidity in the morning varied from 61% in Oct. 1954 to 83% in Jan. 1955 and 65% in March 1955.

Rainfall was 0.52″ in all these months together.

Height and number of leaves and tillers were noted once a fortnight till the plants flowered, more than half the population having flowered being taken as the criterion for the same. After maturity the weights of grains and straw were taken. The results were analysed statistically using the analysis of variance method with 4 degrees of freedom for between and 45 degrees of freedom for within the treatments.

Observations

(*i*) *Growth in height.* The heights attained by the plants are given in Table I and Fig. I. It can be seen that all the treatments result in greater height than the control during the first fortnight (not significant) except the post treatment with IAA. In the third fortnight, on the other hand, the post treatment with IAA, which did not produce any promotion of growth during the first two fortnights, catches up and passes the control, though this is not maintained in the last fortnight of vegetative growth. The greatest height at the end of the fourth fortnight is attained by the pre-treatment with IAA. Treatments with NoXA have not produced any significant increase or decrease in height over control at any stage. So, IAA, as can be seen, is a better promoter of growth of *Sorghum*. The plants at the fruiting stage are shown in Plates 1 to 4.

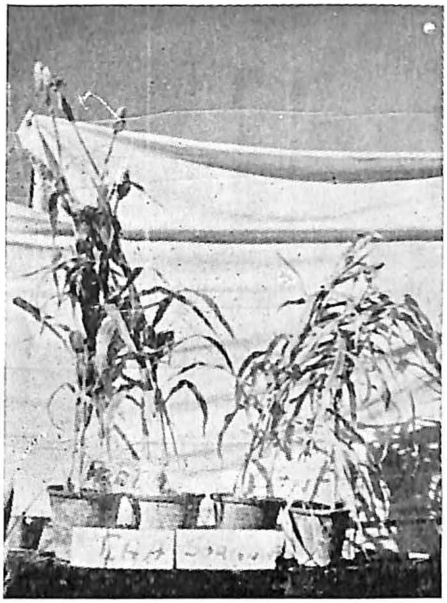
(*ii*) *Vegetative period.* The effect of NoXA can be seen to be to extend the vegetative phase by a fortnight over the other treatments (Table I and Fig. I). IAA does not change the vegetative period.

(*iii*) *Leaves and tillers.* The treatments result in an increase in leaf production generally. Tillering is not usual in *Sorghum* and the control and the post treatments do not produce tillers; but presoaking treatments with both IAA and NoXA have initiated tillers. Between them NoXA initiates more tiller primordia (Table I). But they did not grow up to maturity.

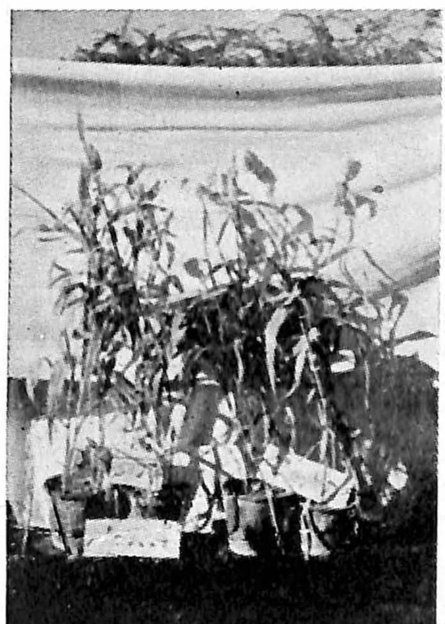
(*iv*) *Grain and Straw.* Only the plants treated with IAA have produced more grains than the control, the NoXA treatments producing less, :though the values are not significant at 5% level (Table II). Production of straw is greater in all the treatments than in the control excepting the post treatment with IAA. Here also the values are not significant at 5% level.

The proportion of grains to straw is in most of the treatments less than in the control, only in the post treatment with IAA it being more. NoXA does not seem to produce any favourable response in the production of grains or straw. The analysis of variance (Table III) for grain and straw shows that the treatments are not significant.

Between IAA and NoXA the former seems to produce better responses in growth and yield than the latter, though the values are not significant.



Plates I and II. Sorghum plants 'pre' and 'post' treated with IAA, along with the control.



Plates III and IV. Sorghum plants 'pre' and 'post' treated with NoXA, along with the control.

Table I

Effect of pre and post treatments with IAA and NoXA on the height, and leaf and tiller number in sorghum.

Observations	"Control."	IAA 'Pre'	IAA 'Post'	NoXA 'Pre'	NoXA 'Post	S. E. of Means	C. D. at 5% level
I Fortnight.							
Height (ins)	9.24	10.54**	8.48	9.46	9.70	0.334	0.927
Leaves (no)	3.40	4.00	4.00	3.60	3.70	0.116	0.322
Tillers (no)	—	—	—	—	—		
II Fortnight.							
Height (ins)	19.33	22.43**	19.27	18.20	16.32	0.990	2.748
Leaves (no)	6.00	6.10	5.00	6.00	5.50	0.21	0.582
Tiller (no)	—	—	—	—	—		
III Fortnight.							
Height (ins)	27.2	30.64*	31.89*	25.65	27.34	1.17	3.848
Leaves (no)	7.6	7.0	8.0	8.2	8.3	0.238	0.661
Tiller (no)	—	—	—	0.4	—		
IV Fortnight.							
Height (ins)	35.01	37.55	34.70	33.98	34.32	0.63	1.749
Leaves (no)	9.0	6.2	7.0	9.2	7.3	0.58	1.610
Tillers (no)	—	0.1	—	0.5	—		
V Fortnight.							
Height (ins)	—	—	—	42.84**	39.46		
Leaves (no)	—	—	—	7.0	7.0		
Tiller (no)	—	—	—	—	—		

* and ** indicate values significant over the control at 5% and 1% level respectively.

Table II.

Effect of pre and post treatments with IAA and NoXA on the production of grains and straw.

Average of 10 plants.

Observation	Con-trol	IAA		NoXA		S. E. of Means	C. D. at 5% level
		pre	Post	Pre	Post		
Grains (gms)	9.02	9.65	9.03	7.85	6.93	0.484	1.340
Percentage of grains over control.		107.0	100.1	87.0	76.8		
Straw (gms)	9.41	11.0	9.09	9.86	9.99	0.320	0 720
Percentage of straw over control		116.9	96.6	104.8	106.15		
Grain 'Straw proportion percent	95.9	87.7	99.5	79.6	69.4		

Table III.

Analysis of variance on the grain and straw yields.

Source of variance	Degrees of Freedom	S S.	M. S.	Observed	from table at 5% level
Grains					
Between	4	130.348	32.587	2.41	2.58
Within	45	606.01	13.47		
Straw					
Between	4	47.331	11.832	1.968	2.58
Within	45	1047.23	23.271		

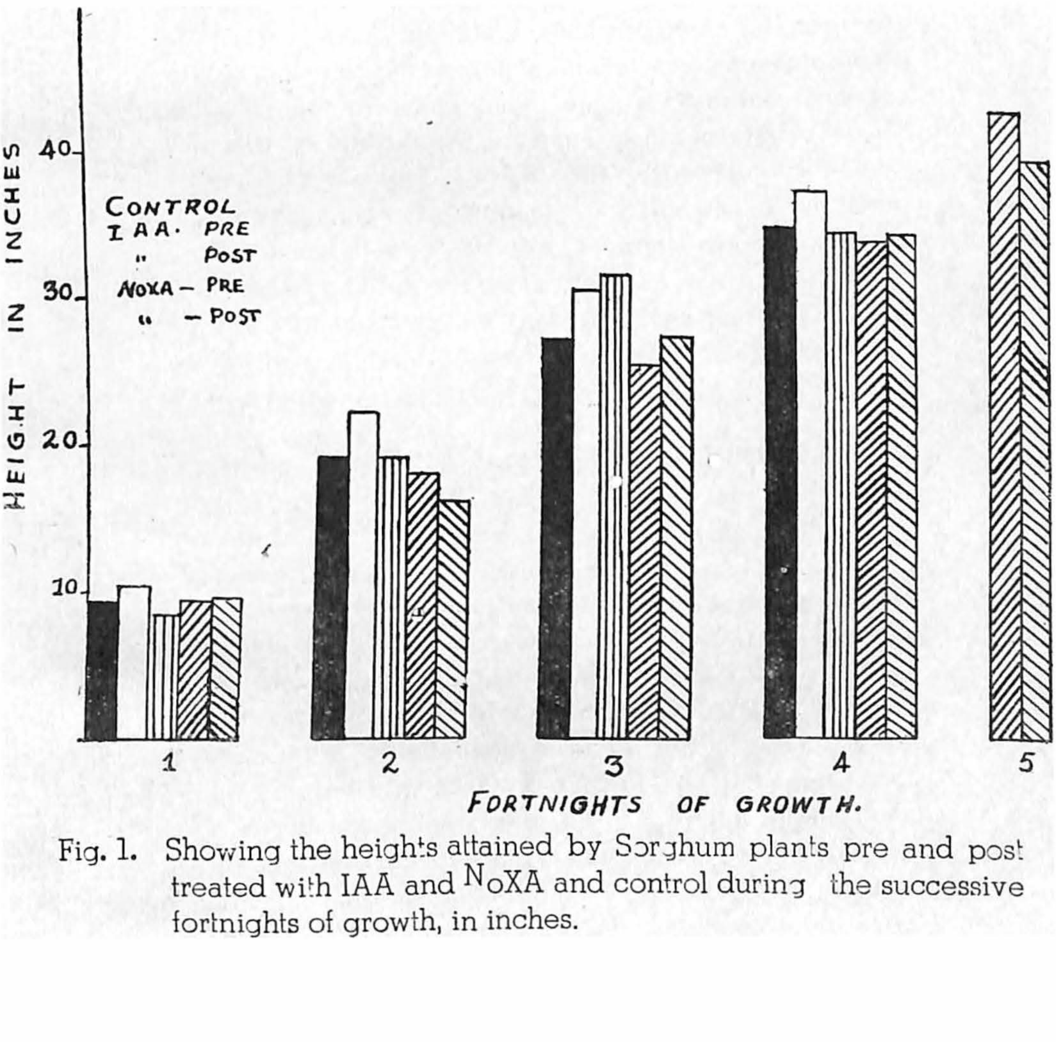


Fig. 1. Showing the heights attained by Sorghum plants pre and post treated with IAA and NoXA and control during the successive fortnights of growth, in inches.

Discussion.

(*a*) *Technique.* The techniques followed in the field of auxin application to crops differ from worker to worker. Stewart and Hamner (1942) and Allard *et al* (1946) have given a continuous supply of the hormone to the soil. Barton (1940), Deshmukh and Kanitkar (1950), Naik (1955), Bharadwaj and Rao (1955) and others have given presoaking of seeds in the hormone solution only. Mullison and Hummer (1949, gave vapour treatments to the seeds. Asana and Mani (1951), Misra and Samantrai (1955) have applied auxins as sprays of aqueous solutions or as lanolin pastes or have injected them into leaves. The authors (1956) have given presowing soaking of seeds followed by the application auxins to the soil during the vegetative phase in another experiment. Thus the techniques followed by the different workers differ. The techniqe followed here is the same as that followed by the authors (1956) in their previous study, namely presowing soaking followed by the application of the auxins to the soil.

(*b*) *Vegetative growth.* As has been pointed out, only the pretreatment with IAA is producing any increased growth in height, all other treatments being ineffective. Between the two auxins tried here, IAA and in this, the pretreatment, seems to be the most advantageous to *Sorghum* for growth in height. Pratt (1938) and Bharadwaj and Rao (1955) found that presoaking of wheat seeds with IAA produced a depressing effect in the initial stages. Our observations do not show any such depressing effect. Asana and Mani (1951) did not find any significant difference in growth by the application of IAA on wheat. Misra and Samantrai (1955) noted no significant increase in height of rice plants on treatment with IAA. Our results show that pretreatment with IAA followed by soil application promotes growth in height in *Sorghum*.

(*c*) *Leaves and Tillers.* Our treatments have resulted in producing more leaves than the control. In the case of tillers, the presoaking treatments have resulted in the initiation of tillers in *Sorghum* which does not usually tiller. These tillers, unfortunately, did not grow up to maturity. Leopold (1949) noted that injections of NoXA reduced tillering. Misra and Samantrai (1955) and Bharadwaj and Rao (1955) found that IAA did not produce any significant increase in the number of tillers in rice and wheat respectively. But, Sen and Verma (1955) observed that presoaking brought about an increase in tiller production in wheat. Our observations are more in accord with those of the latter.

(*d*) *Ear emergence.* It has been pointed out by Harland (1953), Kraus (1954) and others that hormones can be put to a number of uses like inducing rooting of cuttings and grafts, inhibition and stimulation of flowering, preventing or inducing flower and fruit fall *etc.* Recently Sen Gupta (1955) in his survey of this aspect of hormonal activity in plants, has concluded, as has been done by the other authors also that, excepting in the pine apple, in no case has it been possible to initiate the reporductive phase earlier. This is an aspect of great importance in the Rajasthan State, where the growing season is short and where therefore, early maturity will be of benefit. Our observations have not given any favourable results in this direction. Instead, the treatments with NoXA have delayed the initiation of the reproductive phase by a fortnight. The authors (1956) found in a similar experiment on wheat that NoXA delayed the reproductive phase in that plant also.

(*e*) *Grain and Straw.* These are both important in the economy of the Rajasthan State where there is dearth of both fodder and food grains. The treatments tried here have given some encouraging results. Most of the treatments have resulted in producing more straw than the control, the pretreatment with IAA producing the greatest increase namely 16.9% (not significant). In the case of grains, on the other hand, most of the treatments have not yielded favourable results, the only case where there is an increase over the the control being, again, the pretrestment with IAA, yielding 7% more than the control (not significant) (Table II).

The grain/straw proportions indicate that most of the treatments favour greater straw production than grain. McRostie *et al* (1938) and Asana and coworkers (1955) have observed an increase in grain yield with IAA, whereas no significant increase has been observed by Misra and Samantrai (1955) and Bharadwaj and Rao (1955), which trend is followed by our results. Leopold and Thimann (1949) have found that yield is directly correlated with increase in straw. In this study such a correlation is not borne out. The analysis of variance (Table III) indicates that the treatments tried here are not significant.

Finally it is to be mentioned that these studies were made between October and March which is not the growing season of this crop.

Summary and conclusions.

The results of growing *Sorghum* under

(*i*) presoaking seeds in aqueous solutions of 50 ppm of IAA and NoXA for 24 hours and further applying the auxins to the soil at weekly intervals during the vegetative phase of the plants, the 'pretreatments',

(*ii*) presoaking seeds in distilled water for 24 hours and applying the auxins at weekly intervals to the soil during the vegetative phase, the 'post-treatment' and

(*iii*) presoaking seeds for 24 hours in distilled water only, the 'controls'

on growth, maturity and yield are recorded.

There was no pronounced increase in height produced by the treatments, the only exception being 'pretreatment' with IAA.

Leaf production is generally greater and tillers are initiated by the pretreatments, which is not common in the normal plant.

Treatments with NoXA have delayed ear emergence by a fortnight and are not favourable to increased growth.

Both auxins produce more straw, though the increase is not significant. In the matter of grain production, IAA application results in slightly favourable results while NoXA has a depressing effect.

Between IAA and NoXA the former is more suited for this crop.

The authors wish to express their gratitude to Dr. B. N. Mulay, Professor and Head of the Botany Department, Birla College of Science, Pilani for his interest and encouragement and to Prof. B. D. Sharma of the Mathematics Department, Birla College for help in statistical analysis. To the Regional Director, Meteorological Department, New Delhi we are indebted for the relevent meteorological data quoted here.

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5

EFFECT OF PHENYL ACETIC ACID ON THE GROWTH, MATURITY AND YIELD OF RAGI (*ELEUCINE CORACANA*, Gaertn.)

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INTRODUCTION.

Growth regulating substances are now associated with various aspects of growth and development of plants and as Thimann (1954) says "hormones act in or on every organ of the plant and at every stage of development from the cradle to the grave." Efforts at using them to reduce the vegetative cycle and to produce increased yield of crops have not met with consistent results. Bharadwaj and Rao (1955) found the auxins to have no effect on yield of grains and straw, while Asana et al (1955) observed them to produce greater yield, though this is not consistent. But, as Sen Gupta (1955) says, most of the available information is of little use. To find out whether some of these substances have any effect on the vegetative cycle, growth and yield of ragi, these preliminary investigations were undertaken.

MATERIAL AND METHODS

Healthy seeds of ragi, variety K. 1, were soaked for 24 hours in aqueous solutions of Phenyl Acetic Acid (PAA) of the concentrations 0.2, 0.4, 0.6, 0.8, and 1.0 parts per million (ppm) at room temperature, which was between 29°C and 32.8°C. Controls were soaked in tap water for an equal period. After this they were sown in earthernware pots of size 8″ × 8″ filled with soil prepared by mixing 2 parts of garden soil (which is very much lacking in organic matter), 1 part each of river sand and cowdung and sheep manure. To this were added ¼ oz each of ammonium sulphate and superphosphate (potassic manure was avoided as the soil here is rich in this element). After one month's growth another doze of ¼ lb. of cowdung was added to each pot so that nutritional factors may not be limiting. After the first fortnight's growth the plants in each pot were thinned down to 4 and four such pots were maintained under each treatment. At flowering stage a top dressing of ¼ oz each of ammonium sulphate and superphosphate was made.

Every fortnight fresh appliction of the acid was made to the aerial parts of the plants in the form of sprays of the aqueous solution by using the flit sprayer, approximately 5 c.c.s. being sprayed on each plant, till the plants flowered. Height and number of leaves and tillers were noted each fortnight and also the length of the vegetative period.

At maturity the components of yield and weight of straw were determined. The number of spikelets and percentage of grain set were determined for the main panicle only.

The data were analysed statistically using the analysis of variance method with 5 degrees of freedom for between and 90 for within treatments.

The meteorological conditions obtaining during the period of the experiment were:—

Max. Temp. ranged from 94°F in Aug. to 75.3°F in Dec. 1955; Min. Temp. from 78.5°F in Aug. to 44.2°F in Dec. 1955; Rel. Hum. ranged from 84% in Aug. to 75% in Nov. and 86% in Dec. 1955 in the mornings; and from 67% in Aug. to 36% in Nov. and 45% in Dec. 1955 in the evenings. Rainfall was 4.74", 2.75", 5.36", nil and 0.21" during the months of August to December 1955.

OBSERVATIONS

The treatments have in general a depressing effect in the first fortnight, which is lessened with increase in the concentration of the acid. This inhibition is completely overcome in the subsequent periods, when the treated plants attain significantly greater heights over the control. The same is more or less the case with the leaves. (Table I and Fig. I). The plants before flowering are shown in Plate I.

Table I

Effect of various concentrations of PAA on the height, number of leaves and tillers, days of ear emergence and dry matter. Average of 16 plants.

Observations	Con-trol	Treatments 0.2	0.4	0.6	0.8	1.0	S. E. of Means.	C. D. at 1% level.
I Fortnight.								
Height (ins)	1.5	0.89	1.0	1.01	1 07	1.15	0 086	0.3468
Leaves (no)	2	2	2	2	2	2		
Tiller (no)	—	—	—	—	—	—		
II Fortnight.								
Height (ins)	2.5	5 35*	5.69*	5.73*	6.30*	7.6*	0.23	0.9274
Leaves (no)	3 4	4.5	4 6	5.0	5.2	5.3	0.487	2.814
Tiller (no)	—	—	—	—	—	—		
III Fortnight.								
Height (ins)	14.4	20.6*	20.9*	21,9*	22.0*	23 3*	1,27	5.121
Leaves (no)	9	9 4	10.2	11.2	13.4	14.0	0.85	3.427
Tiller (no)	0.2	0.2	0 18	0 17	0.14	0.11		
IV Fortnight.								
Height (ins)	21.8	24.8	25.0	28 6*	29.5*	29.8*	1.3	5.242
Leaves (no)	11.5	12 2	13.0	14.8	16.2	18.0	0.8	3.226
Tiller (no)	0 2	0 2	0 18	0.17	0.14	0.11		
Ear emergence (days)	86 07	81.0	79.4	79.2	75.2	73.8	1.827	7.367
Dry matter (gms)	5.49	5.63	5.93	5 98	6,15	6.31	0,13	0.5242
Percentage of dry matter on control	100.0	102.5	108,0	109.1	112.0	114.9		

* indicate values significant over control at 1% level.

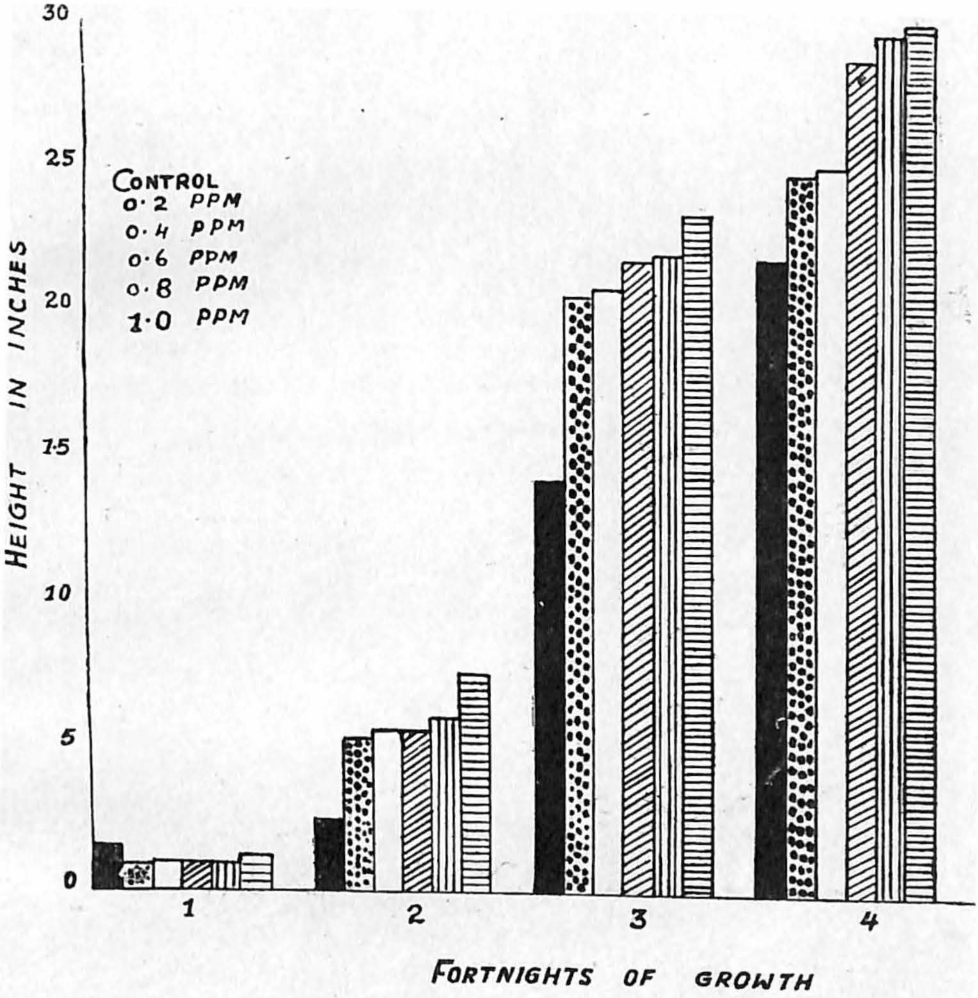

Fig. 1. Showing the heights attained by Ragi plants under the various treatments with PAA and control during successive fortnights, in inches.

Plate I showing the treated Ragi plants just before flowering.

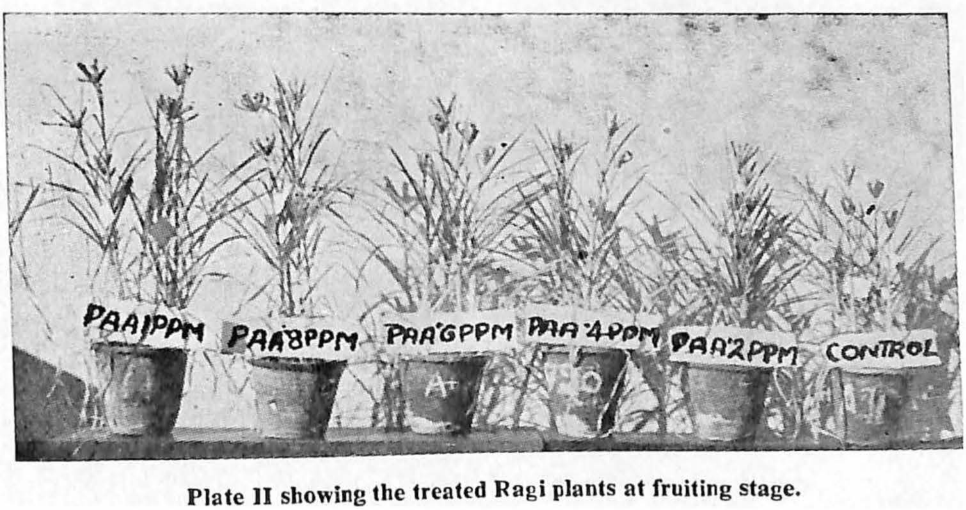

Plate II showing the treated Ragi plants at fruiting stage.

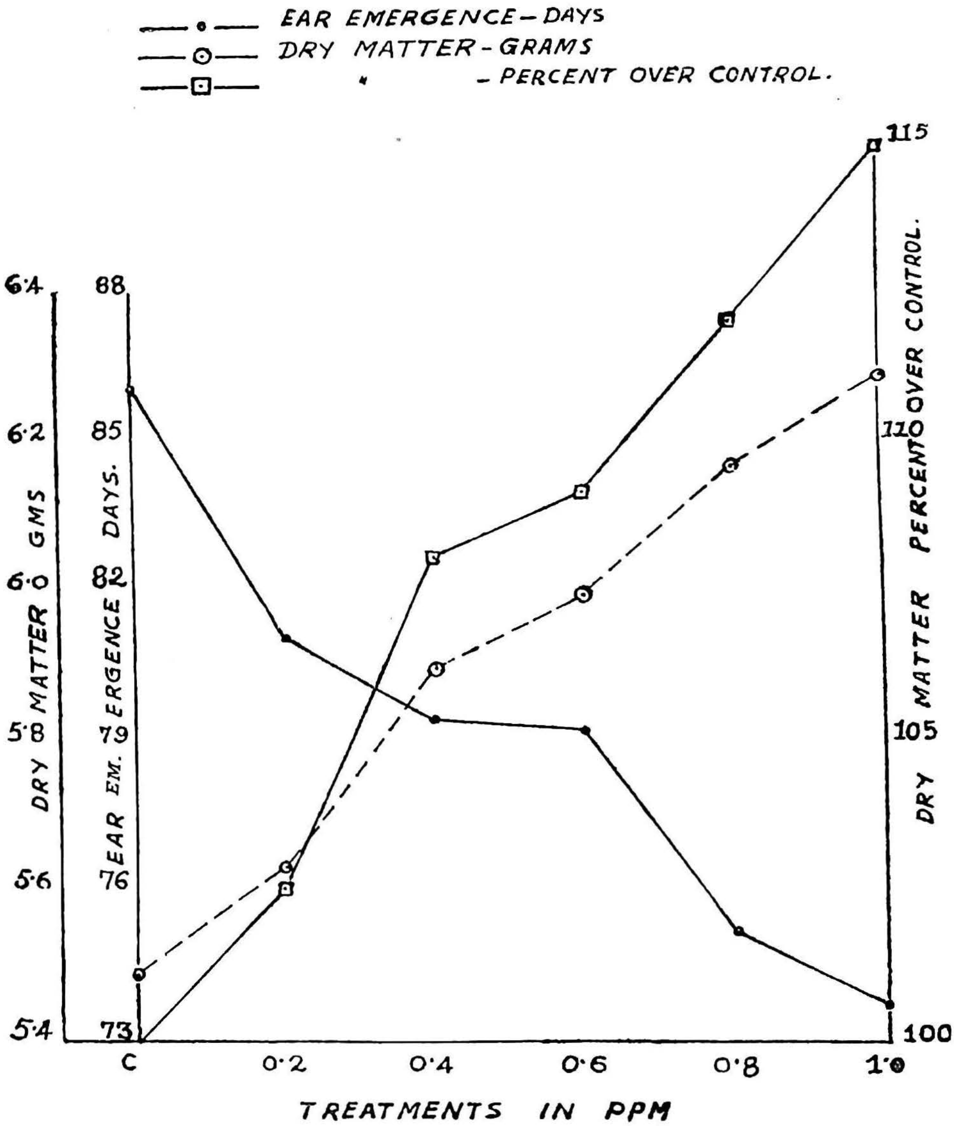

Fig. 2. Showing the effect of treatments with PAA on the maturity and the amount of dry matter in grams and as percentage over control of Ragi plants.

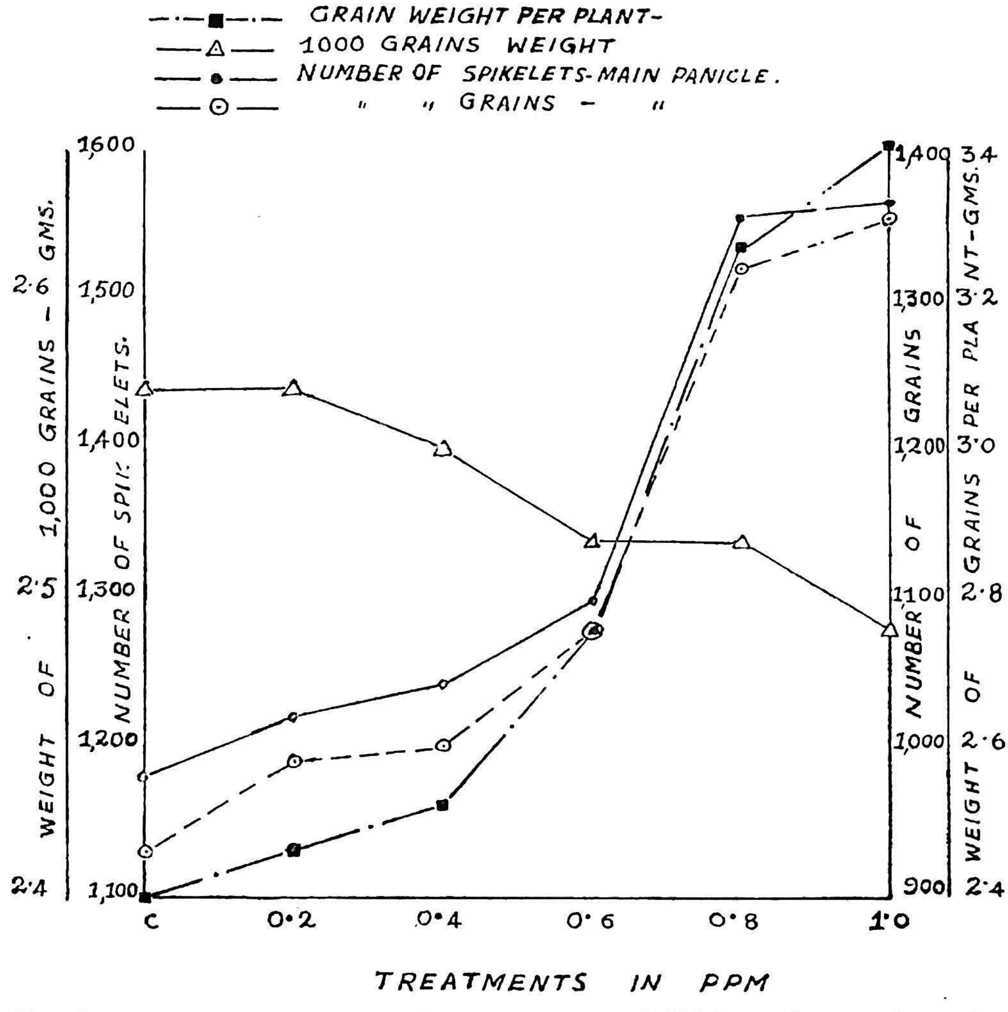

Fig. 3. Showing the effect of the treatments with PAA on the number of spikelets and grains (in the main panicle only) and the weight of grains per plant and the weight of 1,000 grains.

Tillering and production of lateral branches (on aerial shoots only) are both inhibited by PAA.

Ear emergence is hastened by 5·07 to 12.27 days by the various treatments. This earliness in maturity has not affected the amount of dry matter, as this also increasses (Fig. II). The plants at the fruiting stage are shown in Plate II.

Data on yield and its components are presented in Table II. and the analysis of variance in Table III. It can be seen from Tabe II that :—

(1) the number of panicles and the weight of 1,000 grains is decreasing with increase in concentration of the acid, and

(2) the length of panicles, number of grains and spikelets and percentage of grain set per main panicle and the grain weight all show an increase over the control, which is significant at 1% level, the 1.0 ppm treatment yielding 42.5% more grains (Fig. III).

From the analysis of variance it is clear that the treatments are producing results which are significant at 1% level.

DISCUSSION

Technique. A different technique is adopted here when compared to those used by the various workers in the field. Stewart and Hamner (1942) have given a continuous supply of the hormone solution to the soil and this has been followed by Allard *et al* (1946). A number of workers like Barton (1940), Naik (1955), Bharadwaj and Rao (1955) have given presoaking of seeds in the hormone solution to study the effect on growth and maturity. McRostie *et al* (1938) and Hopkins (1940) have used dusting of seeds with the hormone with the same object. Mullison and Hummer (1949) have given vapour treatments to the seeds. Misra and Samantrai (1955), Asana and Mani (1951) and others applied auxins as sprays of aqueous solution or as lanolin paste or injected them into leaves. Pillai and Kurup (1956) have given both presowlng soaking of seeds and further application to soil. Thus, the techniques differ with different workers. But, the field being comparatively virgin and there being no confirmatory evidence as to which technique yields best results, a slightly different technique of combining presoaking seeds in the auxin solution and further application as sprays to the aerial parts at definite intervals during the vegetative period have been tried here.

Table II

Components of yield of ragi plants treated with the various concentrations of PAA. Average of 16 plants

Observations	Control	Treatments 0.2	0.4	0.6	0.8	1.0	S. E. of Means	C. D. at 1% level
Panicles per plant (no)	1.8	1.58	1.4	1.4	1.38	1.25	0.0791	0.3185
Length of panicles (cms)	2.84	2.93	3.08	3.16	3.49	3.55	0.118	0.4758
No. of grains in main panicle	931.7	990.4	1001.6	1082.3	1325.4*	1360.9*	74.75	301.41
Percentage of grain set in main panicle	79.21	82.95	82.97	83.40	86.04	86.71		
Spikelets in main panicle (no)	1179.4	1221.1	1243.7	1297.8	1562.1	1569.5	71.5	288.3
Grain weight per plant (gms)	2.4	2.46	2.52	2.76	3.28	3.42	0.180	0.7258
Percentage of grain weight on control	100.0	102.5	105.0	115.0	136.6	142.5		
Weight of 1,000 grains	2.57	2.57	2.55	2.52	2.52	2.49	0.015	0.0605

* indicate values significant over control at 1% level

Table III

Analysis of variance on data on grain yield.

Source of variance	Degrees of Freedom	S.S.	M.S.	F observed	F from tables 5%	F from tables 1%
Between	5	15.5264	3.1052	3.41	2.31	3.22
Within	90	81.835	0.9092			

Vegetative growth. The growth in height during the first fortnight shows the immediate effect of presoaking. Table I shows that the general effect of this is one of depressing the growth in height. But it is seen that increase in concentration is producing a gradual and consistent increase, though even with the highest strength of the acid used, the height attained is not so much as in the control. It may be that the application of the acid is blocking a process leading to auxin formation as postulated by Thimann (1954). With increase in concentration of the acid, the greater amount of the latter may be acting directly in producing an increase in length. The initial depressing effect seems to be offset completely by the later treatments, as the height of the plants in the later periods shows a consistent rise with rise in concentration, which is continued till the end of vegetative period. The treatments of the plants with PAA as sprays seem to enable them to carry on their metabolic synthetic activities at a higher and faster rate and thus come to the end of their vegetative phase earlier.

Leaves and lateral branches. Presoaking treatments have not affected leaf production in the early stages. But subsequent application as spray during the vegetative period has resulted in increasing leaf production, this increase being proportional to the concentration. Production of lateral branches is inversely proportional to the concentration of the acid. Leopold and Thimann (1949) pointed out that the formation of vegetative buds was not promoted by auxins, while in contrast, Asana *et al* (1955) have found increased production. The observations presented here go to support those of the former authors. Bharadwaj and Rao (1955) also found that presoaking of seeds produced no difference in leaf number in the early stage while in the later stage the plants have more leaves. Their studies did not include the production of branches and so the effect of auxins on this aspect of their plants is not available.

Tiller production is inhibited by all the treatments. The effect of auxin, as far as this aspect is concerned, is not favourble (Table I).

Ear emergence. Observations on the effect of auxins in inducing earliness in flowering in various plants by various workers differ. Galston (1947) found that TIBA favoured vegetative development and was antagonistic to reproductive development. Leopold and Thimann (1949) noted that this is really the effect of auxin concentrations, the lower ones promoting flowering. Misra and Samantrai (1955), Chakravarti and Krishna Pillai (1955) have found evidence which concur with this. But Sen and Joshi (1954) and Pillai and Kurup (1956) have found that auxin appliction prolongs the vegetative cycle. In the treatments reported here it is found that they reduce the vegetative cycle progressively with rise in concentration, 1.0 ppm treatment producing the greatest earliness. The tendency to reproductive development seems to depend upon the concentration of the auxin in the plant. Since only submicro-concentrations have been tried here, the increase in concentration of the acid applied naturally increases its concentration inside the plant which results in inducing earliness in flowering.

Dry matter. The treatments result in an increase in dry matter, the greatest increase of 14.9% being observed in 1.0 ppm treatment. Beneficial effects have been observed in straw production by McRostie *et al* (1938) and Hopkins (1940) by dusting the seeds with hormones. As the technique followed here is differnt their results cannot be compared with this. Bharadwaj and Rao (1955) have reported that presoaking seeds produces an increase in dry matter at low concentrations of the auxins.

Grain yield. Though the number of panicles is decreasing with increase in concentration of the auxin (Table II and Fig. III), the grain yield per plant is found to increase progressively with rise in concentration the treatment with the highest concentration producing 42.5% more grains. Asana *et al* (1955) have found promotive effect on spikelet differentiation. The observations reported here show that increase in yield is directly correlated with increase in straw as seen by Leopold and Thimann (1949) and McRostie *et al* (1938) and which was not observed by Bhradwaj and Rao (1955). Though these plants exhibit greater straw weight, height and yield, their life duration is considerably lesser than that of the control. This shows that the plants are enabled to accumulate more essential constituents by the auxin to result in these increases, as mentioned already; in other words their synthetic metabolic activities are accelerated by the application of the auxin. The analysis of variance shows that the treatments are significant at 1% level indicating that such treatments can result in definite increase in grain yield under similar conditions, because the length of panicles and the number of spikelets and percentage of grain set are increased by the treatments. It is seen that the filling of grains is lesser in the treated plants than in the control, as shown by the weight of 1,000 grains. (Table II).

SUMMARY AND CONCLUSIONS

The effect of presoaking seeds of ragi and subsequent application as sprays of aqueous solution on the aerial parts of Phenyl Acetic Acid of concentrations of 0.2, 0.4, 0.6, 0.8 and 1.0 ppm on the growth, ear emergence and yield of grain and straw are recorded.

The various concentrations of the acid influence the development of ragi plants to a considerable extent. The general effect of all concentrations tried is to promote vegetative and reproductive development, the higher concentrations being more marked in their effect.

The favourable influence of the acid towards promoting growth is manifested by better height, more leaves, greater dry matter and early flower initiation of the treated plants.

Tillering and production of lateral branches are inhibited.

Reproductive growth is also influenced by the treatments as is manifested by the higher grain yield, larger panicles and higher percentage of grain set. But the filling of grains in the treated plants is less than in the control.

From the result of the present investigation, though it cannot be said conclusively, the general effect of Phenyl Acetic Acid used as spray of aqueous solution can be of benefit to the agriculturist in increasing grain and straw yield,

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*originals not seen.

6

A LIST OF POWDERY MILDEWS FROM RAJASTHAN

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The topography of Rajasthan is dominated by the Aravali mountain system which divides the state into two parts, western and eastern. The characteristic feature of the climate is the great extremes of temperature. The winter is severe, minimum falling below the freezing point at many stations and the summer is intensely hot. The western part of the state is the hottest region, the temperature going as high as 122°F. (Sri Ganganagar). Pramanik (1952) has also given in detail the hydrology of Rajasthan. According to him 90 percent of the total rainfall in Rajasthan occurs during the monsoon period (June to September) and only 5 percent takes place during the winter season (December to February). The atmospheric relative humidity is minimum in the hot weather months and maximum during the monsoon months (July to September). Taking the year as a whole, winds from the south, south west or the west are most frequent. During winter, the wind is generally light, the direction being from the north west north and north east.

As regards the vegetation of the area, the flora of the western zone is of the Egyptian type, although many of these plants are found throughout India. In the eastern zone, the flora has a common origin with that of the Gangetic plain.

Diseases caused by the various powdery mildews on crops, vegetables, ornamentals, fruit trees and vines are very common. Although no specific study of the ecology of infection of the mildews has so far been attempted, yet the various climatic factors mentioned above in brief may have an important bearing on their occurrence. It will not be out of place to mention that the incidence of the powdery mildew predominantly takes place in the drier part of the year when the temperature conditions do not reach the maximum of the annual range but the difference between the maximum and minimum is the highest.

The incidence of the powdery mildew in Rajasthan has been studied by the author since 1951 and following is the list of various powdery mildews on different hosts collected so far.

I. **Erysiphe communis Wall. ex Fr. on leaves ond stems.**

1. *Coccinia indica* W. & A. Jodhpur and Bharatpur.
2. *Momordica dioica* Roxb. (only oidial stage) Jodhpur.
3. *Hibiscus esculentus* L. (only oidial stage) Jodhpur and Bharatpur.

II. **Erysiphe graminis tritci El. Marchal. on**

1. *Triticum aestivum* L. Jodhpur and Bharatpur.

III. **Erysiphe polygoni Dc. Ex. Merat.**

1. *Coriandrum sativum* L. (only oidial stage) Jodhpur, Bharatpur and Mt. Abu.
2. *Melilotus polycerata* L. (only oidial stage) Jodhpur and Mt. Abu.
3. *Melilotus parviflora* Desf. (only oidial stage) Bharatpur
4. *Pisum sativum* L. (only oidial stage) Bharatpur.
5. *Phaseclus radiatus* L. (only oidial stage) Bharatpur.
6. *Vigna catjung* L. (only oidial stage, Bharatpur.
7. *Cuminum cyminum* L. (only oidial stage) Bharatpur.
8. *Daucus carota* L. (only oidial stage) Mt. Abu.

IV. **Erysiphe sp.**

1. *Tephrosia purpurea* Pers. (a new host.)
   Fungus appears with usual symptoms of powdery mealy growth on leaves, stems and pods. Ascigerous stage apparent by the end of March every year.
2. *Cleistothecia* are typical with simple unbranched and long appendages. Each cleistothecium contains four to six asci.
3. *Ascospores* : Their usual number is four per ascus which measure 18-24 $\times$ 12-15 μ. Conidial fructification

is predominant and foims the entire source of secondary infection. Conidia are hyaline and elliptic in shape and produced in chains of 4 to 6. They measure 27-33 x 12-15 μ.

V. **Leveillula taurica** (Lev). Arn.

1. *Medicago sativa* L. (only oidial stage) Jodhpur and Bharatpur.
2. *Capsicum annuum* L. var. *acuminatum* (only oidial stage) Jodhpur, Bharatpur and Mt. Abu.
3. *Cyamopsis tetragonoloba* Taub (only oidial stage) Jodhpur and Bharatpur.
4. *Impatiens balsamina* L. (only oidial stage) Jodhpur and Bharatpur.
5. *Allium sativum* L. (only oidial stage) Jodhpur and Bharatpur.
6. *Foeniculum vulgare* Gaentu. (only oidial stage) Jodhpur, Bharatpur and Mt. Abu.
7. *Solanum melangena* L. (only oidial stage) Mt. Abu.
8. *Lycopersicum esculentum* Miller (only oidial stage) Jodhpur, Bharatpur and Mt. Abu.
9. *Trigonella foenumgraecum* L. (only oidial stage) Jodhpur, Bharatpur and Mt. Abu.
10. *Phlox drumondii* (only oidial stage) Bharatpur and Mt. Abu.

VI. **Phvllactinia subspiralis** (Salmon) Blumer.

1. *Dalbergia sissoo* Roxb. Bharatpur and Mt. Abu.

VII. **Phyllactinia** sp.

1. *Lagenaria vulgaris* Seringe (only oidial stage). Bharatpur and Mt. Abu.

VIII. **Sphaerotheca macularis** (Wallr ex. Fries) Wri. B. Cooke.

1. *Rose indica* L. (only oidial stage). Mt. Abu.

IX. **Oidium** sp.

1. *Ocimum sanctum* L. Jodhpur.
2. *Cucurbita pepo* Dc. Jodhpur.

3. *Cosmos bipinnatus* Cav. Bharatpur.

4. *Cucumis trigonous* Roxb. (a new host).
Jodhpur and Bharatpur.
Conidia in chains, measure 24-28 × 15-18 μ. Mycelial septation is variable in length; it measures 6-9 μ. in thickness.

5. *Cucurbita maxima*, Duchesne, (a new host). Bharatpur.
Conidia in chains of 4-6, they measure 24-33 × 15-18 μ.
Mycelial thickness 6-9 μ.

6. *Sesamum indicum* L. (a new host) Bharatpur.
Conidia measur 24-30 × 12-18 μ. Mycelial thickness 6-9 μ.

7. *Phyllanthus* sp. (a new host). Mt. Abu.
Conidia measure 12-18 × 9-12 μ.; they are produced in chains. Mycelium comparatively thinner, measuring 3-5 μ.

8. *Calliopsis elegans* Hort. (a new host). Mt. Abu.
Conidia are produced in short chains of 3 to 7; they measure 25-30 × 15-18 μ. Mycelial thickness is 6-9 μ.

9. *Sonchus oleraceous* L. (a new host). Mt. Abu. Dense mealy growth of the fungus on the upper surface of the leaves. In cases of heavy infections the entire leaf is covered with the mycelial mat with abundant conidial fructification; conidia in chains of 6 to 10. They measure 24-30 × 13-15 μ. Mycelial thickness 6-9 μ.

10. *Luffa acutangula* Roxb. (a new host) Bharatpur.
Conidia measure 27-30 × 15-18 μ. Mycelial thickness 6-9 μ.

11. *Luffa acutangula* var. *amara*. C. B. Clark, (a new host).
Bharatpur. Conidia in chains, measure 21-28 × 15-18 μ.
Mycelial thickness 4-6 μ.

12. *Vitis vinifera* L. Mt. Abu.

X. **Oidiopsis** sp.

1. *Linaria bipartia* Willd. (a new host). Bharatpur.
Conidia measure 42-63 × 12-15 μ. Septation in mycelia is variable ; the thickness of the mycelium is 4-6 μ.

2. *Brachycome acuminatum* Truff. (a new host). Bharatpur and Mt. Abu. Conidia measure 48-60 × 15–18 μ. Mycelial thickness is 4-6 μ.

3. *Asphodelus tenuifolius* Cav. (a new host). Bharatpur and Mt. Abu. Conidia measure 48–60 × 12–18μ. Mycelial thickness 4-6 μ.

4. *Cleome heptaphylla* L. (a new host). Bharatpur. Conidia measure 60-90 × 12-15μ. Mycelial thickness4-6μ.

5. *Celosia cristata* L. (a new host). Jodhpur and Bharatpur. Conidia measure 48-60 × 12-15 μ. Mycelial thickness 4-6 μ.

6. *Hibiscus cannabinus* (a new host). Bharatpur. Conidia measure 57-69 × 15-18 μ. Mycelial thickness 4-6 μ.

7. *Acroclinium roseum* Hook. (a new host). Bharatpur Conidia measure 45-60 × 12-18μ. Mycelial thickness 4-6 μ.

8. *Brassica juncea* L. (a new host). Bharatpur. and Mt. Abu. Conidia measure 30–39 × 12-16 μ. Mycelial thickness 6-8 μ.

9. *Convolvulus arvensis* L. (a new host). Bharatpur and Mt. Abu. Conidia measure 33–45 × 12-15 μ. Mycelial thickness 6–8 μ.

10. *Fumaria parviflora* L. (a new host). Bharatpur. Conidia mesure 36-39 × 12-15μ. Mycelial thickness 6-8 μ.

11. *Escholtzia californica* cham. (a new host). Bharatpur. Conidia comparatively pointed and measure 51-66 × 15-18 μ. Mycelial thickness 6-8 μ.

12. *Peucedanum graveolens* B. & H. (a new host). Bharatpur and Mt. Abu. Conidia measure 36-57 × 12-16 μ. Mycelial thickness 6–8 μ.

13. *Tropeolum majus* L. (a new host). Jodhpur, Bharatpur and Mt. Abu. Conidia comparatively pointed and measure 42-60 × 12-15 μ.

14. *Delphinium ajacis* L. (a new host). Jodhpur, Bharatpur and Mt. Abu. Conidia pointed and measure 48-60 × 15-18 μ. Mycelial thickness 6-9 μ.

15. *Tagetes erecta* L, (a new host). Jodhpur, Bharatpur and Mt. Abu. Conidia pointed and measure 48-60 × 15-18 μ. Mycelial thickness 6-9 μ.

16. *Chenopodium ambrosioides* L. (a new host). Mt. Abu. Conidia measure 57-68 × 13-18 μ. Mycelial thickness 4-6 μ.

17. *Argemone mexicana* L. (a new host). Jodhpur and Mt. Abu. Conidia measure 48-62 × 15-20 μ. Mycelial thickness 4-6 μ.

18. *Pimpinella anisum* L. (a new host) Bharatpur and Mt. Abu. Conidia measure 33-38 × 11-15 μ. Mycelial thickness 4-6 μ.

19. *Malva parviflora* L. (a new host). Bharatpur. Conidia measure 51-62 × 15-17 μ. Mycelial thickness 4-6 μ.

20. *Cassia leschuenaultiana* Dc. (a new host). Mt. Abu. Conidia measure 42-60 × 12-18 μ. Mycelial thickness 4-6 μ.

21. *Verbena venosa* Gill and H. (a new host). Mt. Abu. Conidia measure 42-60 × 12-18 μ. Mycelial thickness 4-6 μ.

22. *Vicia hirsuta* Koch. (a new host). Mt. Abu. Conidia measure 36-52 × 12-15 μ. Mycelial thickness 4-6 μ.

23. *Hibiscus esculentus* L. (a new host) Mt. Abu. Conidia measure 51-63 × 13-15 μ. Mycelial thickness 4-6 μ.

24. *Helianthus annus* L. (a new host). Mt. Abu. Conidia measure 57-66 × 12-18 μ. Mycelial thickness 4-6 μ.

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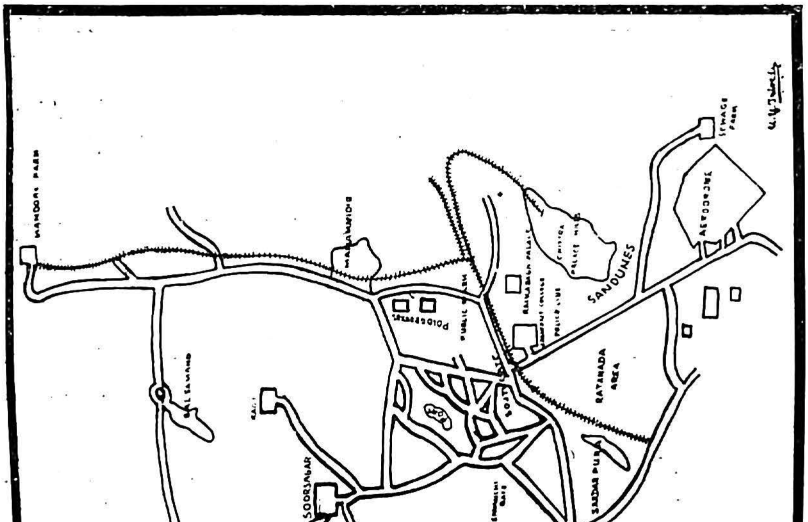
JODHPUR
Scale - 1" = 1 mile
SOORSAGAR
RATANADA AREA
SARDARPURA
SANDUNES
MASOORIA HILL
SANDUNES
AERODROME
KAILANA
BIJOLI
RAJPUT SCHOOL

7

AN ECOLOGICAL NOTE ON SEWAGE-FARM VEGETATION AT JODHPUR.

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INTRODUCTION

The soil complex often shows variations in a given ecological area. The change in soil structure and its condition may be attributed to different factors such as (*i*) Topography (*ii*) Climate and other physical aspects. Changes in the soil may be brought about by the vegetation growing there as well but such changes are of more complex nature and are not usually easy to understand and analyse. The idea that soil conditions are changable gradually and sometimes drastically is of considerable importance in plant succession and vegetational changess are often attributed to this factor in the study of serial stages in succession.

The role of soil in plant succession requires considerable and careful analysis extending over considerable time but soil changes do occur in a given area showing marked changes in vegetation. A careful analysis of such pieces of vegetation in relation to soil give a clue to the role of soil complex on vegetational differences because the climatic and biotic factors are fixed for any given area.

The soils in relation to vegetation have been studied by present authors for a number of different areas near about Jodhpur. These studies have revealed that the soils in different localities are mainly sandy and alkaline, rich in chlorides, poor in water content and humus. Leaving aside the rocky areas, sandy plains show uniform features of vegetation and soil conditions.

Situated towards S. E of Jodhpur city near the aerodrome area is present a low depression (Fig. 1). The Sewage waters from the city are directed to flow to this area and a small Agricultural farm is maintained there. Due to the continuous supply of Sewage water throughout the year, the soils in this area are modified and show certain characterstic changes from those of the soils in the sandy plains.

In order to understand the soil conditions in this area in relation to available natural vegetation, a brief study was planned during 1953-54. The soils were analysed in respect of several physical and chemical features during two seasons of the year and in doing so, soil samples from different quadrats were studied; side by side plant associations growing in the above quadrats were noted. The results are presented here in the form of tables,

SOILS AND THEIR CHARACTERS

The vegetation of the area was studied by frequency quadrats. The soils of the quadrats were brought in air tight tins from three layers :

1. Surface ... ... 0″
2. Sub-soil ... ... 6″ deep.
3. Sub-soil ... ... 1′ deep.

The physical and chemical nature of soils were analysed according to methods used by Wilde (1946) and Piper (1948) and the data were tabulated.

EXPLANATION OF SYMBOLS

1. L. S. — Loamy-sandy.
2. S. G. — Single grained.
3. L. — Loamy.
4. d. — dominant.
5. Co. d. — Co-dominant.
6. a. — abundant.
7. c. — Common.
8. r. — rare.
9. * — very small proportion.
10. † to ‡ — Normal.
11. ¶ — Very high proportion.

Quadrat No. 1

S.No.		Rainy Season. 0"	6" Deep Soil.	1'	Winter Season. 0"	6" Deep Soil.	1'
	PHYSICAL ANALYSIS.						
1.	Texture.	L. S.	L. S.	L. S.	L. S.	L, S	L, S
2.	Structure.	S .G.	S. G.	S. G.	S. G.	S. G.	S. G.
3.	Humus. %	8.725%	4.589%	2.465%	9.236%	4.039%	1.938%
4.	Water content	1.374%	7.685%	8.931%	1.144%	2.446%	4.684%
5.	Porosity.	43.68%	42.75%	39.12%	43.7%	43.3%	39 0%
6.	Aeration.	32.71%	31 85%	27.44%	32.7%	31 7%	27 3%
	CHEMICAL ANALYSIS.						
1.	Carbonate.	†	†	*	†	*	0
2.	Chloride.	*	†	†	*	*	†
3.	Nitrate.	†	‡	‡	†	†	‡
4.	Exchangeable bases	¶	¶	¶	¶	¶	¶
5.	Water Sol. Salts.	.445%	.210%	840%	.631%	.709%	.939%
6.	Potassium.	*	*	*	*	*	*
7.	Calcium.	†	†	†	†	†	†
8.	Total Cations.	481.21	381.573	179.57	497.35	346.31	163.98
9.	pH.	7 to 7.5	7.5	7.5 to 8	7 to 7.5	7 to 7.5	7 to 7.5

Quadrat No. 2

S.No.		Rainy Season. 0"	6" Deep Soil.	1'	Winter Season. 0"	6" Deep Soil.	1'
	PHYSICAL ANALYSIS.						
1.	Texture	—	—	—	—	—	—
2.	Structure.	S. G.	S. G.	S. G.	S. G.	S. G.	S G.
3.	Humus %.	9.728%	6.345%	2.626	5.171	5.447	1.973
4.	Water Content.	4.51%	7.104%	9.211%	1.876	3.255	6.205
5.	Porosity.	44.15%	39.97%	32.49%	41.1%	39.71%	32.25%
6.	Aeration.	31.05%	26.97%	20.67%	31.2%	26.7%	20.58%
	CHEMICAL ANALYSIS.						
1.	Carbonate.	‡	‡	*	†	†	†
2.	Chloride.	†	‡	‡	*	†	*
3.	Nitrate.	*	†	†	0	†	*
4.	Exchangeable Bases.	¶	¶	¶	¶0	¶	¶
5.	Water Sol. Salts.	.840%	.775%	.617%	.484%	.838%	71.596%
6.	Potassium.	†	†	†	*	*	†
7.	Calcium.	*	*	*	*	*	*
8.	Total Cations.	525.57	384.45	158.83	529.6	365.7	171.2
9.	pH.	7 to 7.5	7 to 7.5	7 to 7.5	7 to 7.5	7 to 7.5	7 to 7.5

Quadrat No. 3

S.No.		Rainy Season. 0"	6" Deep Soil.	1'	Winter Season. 0"	6" Deep Soil.	1'
	PHYSICAL ANALYSIS.						
1.	Texturs.	L	L	L	L	L	L
2.	Structure	S. G.	S. G.	S. G.	S. G.	S. G.	S. G.
3.	Hums%.	7.121%	5.353%	3.129%	7.914%	4.201%	2.337%
4.	Water content	1.54%	7.104%	9.211%	.639%	2.495%	4.787%
5.	Porosity	47.74%	40.63%	27.72%	47.7%	40.5%	24.5%
6.	Aeration	37.3%	29.33%	12.5%	37.3%	29.2%	12.52%
	CHEMICAL ANALYSIS.						
1.	Carbonate	‡	‡	*	†	†	†
2.	Chloride	†	‡	‡	*	†	*
3.	Nitrate	*	†	†	0	†	*
4.	Exchangeable Bases	¶	¶	¶	¶	¶	¶
5.	Water Sol. Salts.	.824%	.635%	.213%	.689%	.476%	.173%
6.	Potassium	†	*	*	*	*	*
7.	Calcium	*	*	*	*	0	0
8.	Total Cations	255.27	335.6	221.35	225.75	349.2	163.45
9.	pH	7 to 7.5	7.5	8.	7 to 7.5	7.5	8.

Quadrat No. 4

S.No.		Rainy Season. 0"	6" Deep Soil.	1'	Winter Season. 0"	6" Deep Soil.	1'
	PHYSICAL ANALYSIS.						
1.	Texture.	L	L	L	L	L	L
2.	Structure.	S. G.	S. G.	S. G.	S. G.	S. G.	S. G.
3.	Humus.	9.728%	6.345%	2.626%	9.504%	5.912%	2.182%
4.	Water content.	1.99%	4.015%	7.065%	.842%	2,317%	3.359%
5.	Porosity.	46.27%	41.58%	31.86%	46.0%	41.39%	31.4%
6.	Aeration.	36.95%	31.78%	23.26%	36.7%	31.6%	23.3%
	CHEMICAL ANALYSIS.						
1.	Carbonate.	†	*	*	*	0	*
2.	Chloride.	*	‡	‡	*	*	‡
3.	Nitrate.	¶	¶	¶	¶	¶	¶
4.	Exchangeable Bases	¶	¶	¶	¶	¶	¶
5.	Water Sol. Salts.	1.653%	.991%	.810%	1.49%	.381%	.217%
6.	Potassium.	*	*	*	*	0	0
7.	Calcium.	*	*	*	*	0	0
8.	Total Cations.	464.29	773.55	132.12	484.96	732.53	213.31
9.	pH.	7 to 7.5	7 to 7.5	7 to 7.5	7 to 7.5	7 to 7.5	7.5

A critical survey of above tables leads to the following general facts with regard to physical as well as chemical nature of soils.

PHYSICAL NATURE

The soils of the investigated area are Sandy loamy, approaching to loamy condition and single grained in structure yet show compactness. The humus content is fairly good and reaches upto 9% and is usually larger in surface layers. The water holding capacity is rich ranging from 2% to 10%. There is a general increase in this value from surface to deeper layers. Porosity and aeration increase with depth ranging between 30% to 40%. These values approach those of sandy soils in plains.

During the winter season, there is an increase in humus content and a little decrease in water content. Porosity and aeration values do not show any change to a marked extent. Similar is the case with texture and structure of the soil.

CHEMICAL NATURE

Chloride and nitrate contents are the characteristic factors dominating in this area. While carbonates, potassium and calcium contents are very poor, the percentage of water soluble salts reaches upto 1.7% and there is a general decrease towards the deeper layers. The surface soils possess larger amount of water soluble salts; similar is the case with total cations of the soil. The pH in soils in uniform and ranges between 7.51 to 8.

As pointed out by Raychaudhary (1952) salts of soils in desert are brought to surfacs layers during winter due to (*i*) low rainfall and (*ii*) high evaporation. The flow of Sewage water also supplements the same fact. This ultimately results in an increased percentage of water soluble salts and total cations value. There is a decrease in carbonate and potassium contents. The pH value fairly remains constant.

PLANT ASSOCIATIONS AND THEIR FREQUENCY

RAINY SEASON.

Quadrat No. 1

Name of Species.	Frequency.
1. *Zizyphus rotundifolia*	d.
2. *Z. jujuba*	co. d.
3. *Prosopis spicigera*	c.
4. *Eleusine indica*	a.
5. *Cyperus*. sp.	r.

Quadrat No. 2

Name of Species.	Frequeney.
1. *Digera arvensis*	a.
2. *Chenopodium album*	co. d.
3. *Amarantus virdis*	d.
4. *A. blittii*	d.
5. *Mollugo hirta*	c.
6. *Eragrostis pilosa*	r.
7. *Pennisetum cilearis*	r.
8. *Cucurbita pepo*	c.
9. *C. maxima*	r.
10. *Oscimum canum*	r.

Quadrat No. 3

1. *Achyranthes aspera*	co. d.
2. *Ailanthus excelsa*	r.
3. *Xanthium strumarium*	d.
4. *Pennisetum cilearis*	c.

Quadrat No. 4

1. *Dtura alba*	d.
2. *Chloris virgata*	c.
3. *Solanum xanthocarpum*	co. d.

WINTER SEASON.

Quadrat No. 1

1. *Zizyphus rotundifolia*	d.
2. *Z. jujuba*	co. d.
3. *Prosopis spicigera*	c.

Quadrat No. 2

1. *Amarantus viridis*	d.
2. *A. blittii*	d.
3. *Chenopodium album*	co. d.
4. *Digera arvensis*	a.
5. *Mollugo hirta*	r.
6. *Oscimum canum*	r.
7. *Cucurbita maxima*	r.

Quadrat No. 3

Name of species.	Frequency.
1. *Xanthium strumarium*	d.
2. *Achyranthes aspera*	co. d.
3- *Ailanthus excelsa*	r.
4. *Digera arvenis*	c.

Quadrat No. 4

1. *Dlura alba*	d.
2. *Chloris virgata*	r.
3. *Digera arvensis*	co. d.
4. *Solanum xanthocarpum*	a.

DISCUSSION

The soils are loamy sandy in texture and single grained in structure. They are appreciably high in humus content and the water content also increases in the deeper layers of soils. In respect of the humus content and water content these soils thus stand in constrast to the soils in the sandy plains.

Chemically the soils show a netural to alkaline, pH value (7.5 to 8) similar to sandy plains of Jodhpur. The more characteristic feature in this area is the presence of abundant nitrates in the soil. A survey of quadrat study of vegetation shows a number of plant species from sandy plains such as *Digera arvensis*, *Mullugo hirta*, *Chenopodium album*, *Eleusine indica*, *Eragrostis pilosia*, *Cyperus species* and *Pénnisetium ciliaris* grow. But same species such as *Datura alba*, *solanum xanthocarpum* and *Xanthium strumarium*, *Achyranthes aspara*, *Amarantus blitii* form dominant and co-dominant components of the vegetation in the investigated quadrats. This indicates that the above species are characteristic of such areas which possess high nitrate content of the soil. The same fact is observed by the present authors and a number of previous workers. For example *Solanum xanthocarpum* and *Datura alba* have been observed to grow in a number of out of the way localities near about Jodhpur where there is an accumulation of nitrogenous waste materials. As pointed out by Barucha and his students the above species seem to be Nitrofilous.

SUMMARY

The present study of Sewage form includes an investigation into the Floristic composition in relation to soil conditions. The topography of the area has been described. The study of soils on the basis of Physical and Chemical nature has been made. The prevailing vegetation has been analysed by quadrat method. The exact nature of soil has been finally discussed.

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8

PROGRESS OF DESERT ECOLOGY IN INDIA DURING 1950–56

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(Translation of an article published in the Botanical Journal of Academy of Sciences U. S. S. R. Vol. XLI, 1956.)

Considerable interest has lately been shown in the study of the vegetation of the Indian Desert. Some of the work done has been reviewed in a recent paper by Shantisarup and Bhandari 1955.

A list of plants of Jodhpur and its neighbourhood was prepared after a study of many years and published by the author in 1951. This was revised in 1954. Sankhala (1951) published a list of plants of N. W. Rajputana. Dass and Shantisarup (1951) studied the Biological Spectrum of the Flora of the Indian Desert. A study in the Plant Ecology of the Northeastern Desert areas of Pilani and its neighbourhood was made by Mulay and Ratnam (1950); while Ramchandran 1950 studied the Grasses of that area. Vegetation of the hilly tracts of the Eastern Rajputana (Lohargal) was surveyed by Ratnam (1951). Shantisarup 1952 a contibuted a paper on the Plant Ecology of Jodhpur and its neighbourhood. The occurance of Ephedra in the Indian Desert was reported by Bhandari (1953).

In recent years considerable interest has been aroused in the Desert and its reclamation. The Government of India, Ministry of Food and Agriculture established a *DESERT AFFORESTATION RESEARCH STATION AT JODHPUR*, which has done considerable afforestation work in the desert and is doing important research in Silviculture of indigenous species and the introduction of exotic desert plants.

The desert Research station has also organised (a) the creation of Oases of vegetation around various public institutions and stations (b) creation of a belt approximately 400 miles long and 5 miles wide towards the Western border of the Indian Desert (c) establishing shelter belts along selected roads and railway lines, nurseries at many centres and afforestation of blocks of not less than a thousand acres each in different types of soils,

The National Institute of Sciences, India organised a symposium on The Rajputana Desert (1952). Shantisarup 1952a in an extensive paper dealt with the extent and development of the Desert and the influence of climate, edaphic and biotic factors in the distribution of vegetations of the area.

Puri (1952) reviewed the position of plant ecology of the deserts of Rajasthan and Saurashtra. Agarkar (1952) and Biswas (1952) also contributed papers on the plant Ecology of the Rajputana Desert. Papers on other sciences are too numerous to mention here.

Shantisarup (1952) contributed another paper on the Ecology of N, W. Rajasthan in the Desert Symposium which was held by the Research Council of Israel, at Jerusalem.

A series of contributions on the subject followed from the Botany Department, Jaswant College, Jodhpur. Shantisarup and Vyas (1953, 54) studied the ecology of some selected areas of Jodhpur Tehsil. The vegetation in relation to soil was studied by Shantisarup and Krishan Dutt (1954), Ratnam and Joshi (1952) studied the ecology and vegetation near about a temporary pond at Pilani (E. Rajasthan). Antoecology of desert species like *Tephrosia Purpurea* Pers. and *Gynandropsis pentaphyalla* D. C. were studied by Suryapal Singh (1953) and Tandon (1954) under the guidance of Shantisarup. Bakshi and Kapil (1953, 54) studied the autecology of *Mollugo Nudicaulis Lamk* and *Mollugo Cerviana* Ser. respectivoly.

Ratnam and Kapoor (1953) studied the tuberization of roots of common Indian Desert plants, Ratnam and Dau Lal (1954), Bhargava (1954) and Prithvi Singh (1954) studied some aspects of the Physiology of the Desert Plants.

Biswas and Rao (1953) contributed a paper on the ecology of Rajputana Desert. Shantisarup (1954) studied the water economy of plant life of semi-arid regions of Jodhpur, Hydrophytes of Jodhpur and Halophytes of Indian Desert were studied by Shantisarup (1954, c. 1954, d.) Puri and Shantisarup (1954) studied the Vegetation Types of the Rajputana Desert. Bakshi (1954) published a list of plants of Pilani and neighbourhood with some ecological notes. Nair and Joshi (1954) contributed a paper on the ecological features of sand dune areas of Pilani. The author is studying the Desert Flora of Rajasthan under a UNESCO aided project. Dr. F. R. Bharucha is making Phytosociological study of the vegetation of the Desert with the help of a similar grant from UNESCO.

The condition of Indian Desert and its problems have been reported by Dr. Gurr in a recent publication of F. A. O. (1955). Shantisarup (1954 d) summarised the problem of the immobolisation of the Indian Desert at the Symposium on Applied Ecology.

A number of young botanists are being trained under the guidance of Dr. Puri and the author in Desert Ecology and the problem is being tackled in its multifarious aspects.

A recent UNESCO publication *Arid Zone Research VI* contains an intersting article by Prof. F. R. Bharucha on Reviews of Research in Plant Ecology of Afghanistan India & Pakisthan, *Paris* 1955. Prof. Shanti Sarup published a list of *Plants of Bikaner* 1957 and *Plants* of Jaisalmer in 1958. B. M. Sharma has been working on the weeds of the Semi-Desert area. M. C. Joshi has worked on the Plant Ecology of the sandy areas of the Desert. (M. C. Joshi Plant Ecology of Bikaner of its adjacent areas etc. Jour Ind. Bot. Socity Vol. *XXXV*, No. *4* 1956 P 495-511,)

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9
HYDROPHYTES OF JODHPUR

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Jodhpur is situated on the fringe of the great Indian desert. The desert extends from the Aravallies (24° N) to Sind (32° N). It is continued into the Rann of Kutch (70° E) and approaches the fertile lands (76° E) lying a 150 miles away at the foot of the Himalayas. It is an extensive lowland. Rock is exposed at two widely separated areas in the West of Barmer and the North East of Pokaran. There are smaller plateaus such as the Kailana-Jodhpur, Mandore plateaus extending to the North of the city of Jodhpur for many miles and the plateau of Jaisalmer. Most of the country is sterile and sandy. In the Western and the Northern parts of the desert the rainfall does not exceed 3" to 4" and the soil is poor. Rainfall gradually increases towards the south and south east. In the central region the average is about 13". In the south eastern parts of the Rajasthan near the foot of the Aravallies the annual rainfall generally exceeds 25". Ninety percent of the rainfall in the area occurs during the Monsoon season that is from June to September. The rain water is conserved in artificial tanks in the rocky valleys and in the plains also. In the vicinity of the city of Jodhpur there are six such water reservoirs. A general feature of the lowland is the formation of depressions. During the rainy season water drains to these basins, the larger ones forming pools at a few places. The catchment area of these is increased and bunds of various dimensions may be erected. Most of the villages are situated near such places where there is a big depression and the water is drained into the area from the neighbouring upland for many miles.

Much interest has been aroused in the ecological studies of the vegetation of the desert areas. These are being planned as purely academic research and as an aid to immobilisation of the sand. Studies on the Hydrophytes of Jodhpur would also be of considerable interest from many points of view.

Considerable work has been done in the western countries on the Systematics and distribution of the water plants. One of the earliest and monumental works which stimulated studies on water plants was that of Arber (1920). Fassett (1940) and Muenscher's (1944) work on the systematics of the water plants of United States of America are other important contributions to the subject. The work of Skene (1924) is valuable for the discussions on insectivorous plants, pollination, seed dispersal and seed germination in aquatic plants.

The vegetation of the tropics and subtropical lakes has yet to be studied. Studies of the Hydrophytes of India have not received much attention. Mukerjee's (1926) work on the vegetation of the Dal lake region of Kashmir dealt with the factors operating and their effect on the growth and development of plant associations in the region as well a detailed study of the principal plant communities and the economic products of the Dal lake. Pioneer work in plant Ecology of water plants was thus started by Late Dr. S. K. Mukerjee but his sad demise in the prime of life cut short a promise of school of plant ecologists. A work of more comprehensive nature is that of Biswas and Calder (1937) on the Water and Marsh plants of India. The book had gone out of print and has now been revised and is under print. Some contributions on the different aspects of the fresh water hydrophytes of different places (Gunjikar 1947, Lakshmanan 1950, Misra 1946, Mirashi 1954) in India have appeared from time to time, Aquatic and Marsh species have been mentioned by Hooker 1880) Cooke (1903) Haines (1925) and others. Navalker (1940, 1941) and Bharucha (1940, 1941, 1942, 1948, 1949 and 1950 have published a series of papers on studies in the Ecology of Mangroves, Earlier Blatter (1905) had discussed the mangroves of Bombay Presidency and their Biology. Similar studies might well be conducted for other parts of India. Of the few works on the flora of the Desert, only Blatter and Halberg (1918) mention aquatic formations. They visited the area in October and November 1917 and noted a number of species in the different tanks as follows:—

Jodhpur, Kailana.	*Chara* Sp. *Potamegeton crispus* & *Najas australis.*
Balsamand.	*Trapa bispinosa.*
Phalodi.	*Valisneria spiralis.*
Bap.	*Potamogeton pectinatus, Najas graminee Najas Welwitschii* & *Chara* sp.
Jaisalmer.	Gharisar lake, Bada Bag, Amarsagar — Not of much interest Botanically.
Seu & Badka.	*Nymphaea lotus* & *Limnanihemum parviflorum, Chara* sp.

They conclude that the submerged flora is rather poor and very local. The occurrance of *Najas australis* and *N. Welwitchii* within this region is very interesting, both plants being new for India.

A survey of the hydrophtes of the water reservoirs of Jodhpur and its neigbourhood has been made during the last few years. Most of these reservoirs supply drinking water to the town and ordinarily do not dry out. The Umaid Sagar at Chopasani has a sandy bottom and water dries up soon and some parts of the lake are used for cultivation of winter crops. At other places semi aquatic plants such as *Lippia nodiflora*, *Ammannia baccifera* and *A. multiflora*, *Bergia ammannioides*, *Alternanthera sessilis* and a few Cyperaceso are found. *Trapa bispinosa* is cultivated at the shallow end.

Climatic data for Jodhpur are given in Table 1.

Table No. 1.

Climatic data for Jodhpur.

(Average for some years)

	Temperature in °C			Rainfall. in inches	% Humi-nity.
	Max.	Min.	Mean.		
January	76.1	49.6	62 85	0.15	46
February	80.0	53.0	66 5	0.24	42
March	91.7	62.0	77.0	0.11	33
April	100.7	72.6	86.65	0.13	29
May	106.7	80.2	93.45	1.41	42
June	104.6	82.7	93.65	1.42	37
July	97.7	80.5	89.1	3.97	70
August	93.3	78.0	85.65	4.48	76
September	94 9	75.5	85.2	2.40	69
October	96.9	67.5	82.2	0.32	43
November	89.7	88.5	74.1	0.11	38
December	97.7	52.7	62.2	0.11	44
Annual	92.6	68.8	80.7	14.21	47.41

Ecological studies on the hydrophytes of Jodhpur and its neighbourhood are in progress. The relation of environmental factors to aquatic plants are quite interesting. Welch (1935) has discussed the nature of fresh water environments, the influence of physical and chemical conditions on the biota, and the role of vascular aquatic plants. Methods of determing the environmental conditions of fresh water habitats are described by Welch (1949). Shirley (1945) studied the penetration of light into water and means of its measurement. The methods of seed germination, environmental requirments for breaking dormancy, and the relation of progression, and secession of water levels to germination of seeds, sprouting, survival and growth forms of wetland and acquatic plants are some of the many aspects of the problem.

At present a list of the water plants found here is given below as a result of the preliminary survey of the area. Water plants are here considered as plants that "grow in water, in soil covered with water or in soil that is usually saturated". Weaver and Clements 1938. According to this definition hydrophytes would include both wetland and aquatic species. An account of their ecology, phenology and physiological anatomy would be given later on. These plants occur in the artificial lakes, reservoirs and pools and channels formed on account of the leakage of water from some of the tanks.

The following Aquatic associations are common:—

1. **Eicchornia—Potamogeton association**

Eichornia crassipes Solms	Dominant
Potamogeton crispus Linn	Co-dominent
Lemna minor Linn	Common
Algae-species of *Spirogyra*, *Oedogonium* etc.	Abundant

2. **Hydrilla-Valisneria association**

Hydrilla verticillata Casp	Dominant
Valisneria spirallis Linn	Co-dominant
Ceratophyllum demersum Linn	Abundant

3. **Ceratophyllum Valisneria association**

Ceratophyllum demersum Linn	Dominant
Valisneria spirallis Linn	Abundant

Valisneria appears later. Pure association of these and other plants are also common.

Water Plants Found at Jodhpur

I. NYMPHAEACEAE	1. *Nymphaea stellata* Willd.
	2. *Nymphaea lotus* Linn.
	3. *Nelumbium speciosum* Willd.
II. CAPPARIDACEAE	4. *Cleome Chelidonii* Linn.
III. ROSACEAE	5. *Potentilla desertorum*. Bunge.
IV. LEGUMINOSAE (Papilionaceae)	6. *Sesbania aegyptiaca* Pers.
V. ELATINACEAE	7. *Bergia ammannioides* Rokb.
	8. *Bergia odorata* Edgew.
VI. LYTHRACEAE	9. *Ammannia baccifera* Linn.
	10. *Ammannia pentandra* Roxb
	11. *Ammannia multiflora*. Roxb.

VII. ONAGRACEAE	12. *Trapa bispinosa* Roxb.
	13. *Jussisea suffruticosa* Linn.
VIII. UMBELLIFERAE	14. *Centella asiatica* Urb.
IX. COMPOSITAE	15. Xanthium strumarium Linn.
	16. *Eclipta erecta* Linn=(*Eclipta alba* Hassak.)
	17. *Caesulia axillaris* Roxb.
X. GENTIANACEAE	18. *Canscora diffusa* Br.
	19. *Limnanthemum nymphaeoides* Linn.
	20. *Limnanthemum parvifolium* Qrish.
	21. *Limnanthemum cristatum* Griseb.
XI. CONVOLVULACEAE	22. *Ipomoea aquatica* Forsk.
	23. *Evolvulus alsinoides* Linn.
XII. LENTIBULARACEAE	24. *Utricularia stellaris* Linn.
XIII. ACANTHACEAE	25. *Hygrophila suffroticosa*
	26. *Asteracantha longifolia* Nees.
XIV. VERBENACEAE	27. *Lippia nodiflora* Rich.
XV. SCROPHULARIACEAE	28. *Torenia bicolor*, Dalz.
XVI. AMARANTACEAE	29. *Alternanthera sessillis Br.* =(*Alternanthera triandra*)Lam.
XVII. POLYGONACEAE	30. *Polygonum glabrum* Willd.
	31. *Polygonum plebejum* R. Br. var *indica* Hook.
	32. *Polyonum amphibium* Linn.
XVIII. CERATOPHYLLACEAE	33. *Ceratophyllum demersum* Linn.

Monocotyledoneae

XIX. HYDROCHARITACEAE	34. *Hydrilla verticillata* Prosl.
	35. *Valisneria spiralis* Linn.
XX. COMMELINACEAE	36. *Commelina nodiflora* Solms.
XXI. PONTEDERIACEAE	37. *Eichchernia crassipes* Solms.
XXII. TYPHACEAE	38. *Typha angustifolia* Kurz.

XXIII. LEMNACEAE
39. *Lemna minor* Linn.
40. *Wolffia arrhiza*, *Wimm.*

XXIV. POTAMOGETONACEAE
41. *Potamogeton crispus Linn.*
42, Potamogeton pectinatus Linn.
43. *Potamogeton natans* Linn.

XXV. NAIADACEAE
44. *Najas minor* Ellion.
45. *Najas graminea* Del.
46. *Najas australis* Bory.
47. *Najas Welwitschii* Rendle,

XXVI. CYPERACEAE
48. *Cyperus pygmaeus*, Retz.
49. *Cyperus aristatus* Rottb.
50. *Cyperus iria* Linn.
51. *Cyperus bulbosus* Vahl.
52. *Fimbristylis tenera* Roem.
53. *Scirpus quinquefarius* Ham.
54. *Scirpus Hallii* Gray.

XXVII. GRAMINEAE
55. *Sporobolus glaucifolius* Hochst.
56. *Eragrostis pilosa* Beauv.

Pteridophytes

XXVIII. MARSILEACEAE
57. *Marsilea quadrifolia.*
58. *Marsilea aegyptiaca.*

Algae

XXXIV. CHARACEAE
1. *Chara zeylanica.*
2. *Chara fragilis.*
3. *Chara braunii.*
4. *Nitella batrachosperma.*

The Origin of the Water Flora of the Desert Area.

The land flora of the desert comprises a number of species which are found in the various parts of India, in spite of its being Egyptian in origin e. g. *Gynandropsis pentaphylla. Abutilon indicum, Tribulus terrestris, Tephrosia procumbens, Trichodesma indicum. Lippia nodiflora, Aerua javanica* and *Achyranthes aspera.*

Some other plants which are of tropical African origin, are found in the semi-arid regions and are also widely diffused all over

India, such as species of *Ipomaea* and other Convolvulaceae and species of *Corchorus* and *Triumfetta*. Some plants generally of the Xerophytic type extend along Arabian and Russian coasts to Sind and then to the Punjab, Rajasthan and the drier parts of the Gangetic plain, such as *Capparis aphylla, Cocculus laeba, Alhagi maurorum, Acacia arabica. Prosopis specigera.* species of *Zizyphus* and *Calotropis, Citrullus colocynthis. Heliotropium undulatum, Salvia aegyptiaca, Lycium europaeum* and several Chenopodinaceae.

It may be believed, therefore, that the flora and possibly the fauna of the desert area might have come from Sind, Baluchistan, Arabia, Persia, Egypt etc.

The flora of the Aravalli Zone and the plains may have a common origin with the flora of the gangetic plain.

The water plants of the region also are generally common in the other neighbouring parts of the country and might have been introduced from the neighbouring regions. A few species noted earlier as having not been reported from other places in India might have been introduced from abroad by foreign visitors or vists of princes and other persons to foreign lands or by other collectors. Some of these tanks were repository of fish kept by princes and plants were introduced in these tanks as an aid to fish culture. The water plants supply shade, shelter, cover food and support for insects.

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10

THE HALOPHYTES OF THE INDIAN DESERT

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Alkaline soils are characteristic of regions where desert conditions prevail. The principal alkaline lakes of India are in (Sind and) Rajputana. Sambhar lake 26° 55' : 75° 11' now situated in the Jaipur Division of Rajasthan is source of large quantities of salt and is a potential source of sodium sulphate and sodium carbonate. It has an area of 90 sq. miles when full during the monsoon.

There are other smaller lakes : at Didwana, 27° 23' : 74° 35' which covers an area of about 4 sq. miles and the salt basin of Pachbhadra 25° 50' : 70° 10' in about 12 sq. miles. The Pachbhadra salt basin consists of a long oval depression about 7 to 8 miles long and 3 to 7 miles broad. It appears that at some remote period. it must have been the bed of a river. It is about 60 miles South West of Jodhpur and a few miles North of the right bank of the river *Luni*. It situated in a scantily cultivated country.

Lunkaransar is a small lake situated at a distance of 1=51 miles N. E. of Bikaner city on the Bikaner Bhatinda Railway line. The lake in elliptical in shape. Common salt is manufactured in open salt pans by concentration.

Besides these regular lakes there are other areas, also where saline water of various specific gravity is available. Some of these are Phalodi, Kanod, Bap, Pokaran, Deoria, Sachor, Rewana, Chanod etc,

The waters of the Luni River arising from the west of the Aravalli range are saline. It covers a big tract which is specially rich in salt from Pachbhadra downwards to the south into the Rann of Cutch.

The Rann of Cutch. According to Wadia (1919) the Rann of Cutch is a flat unbroken surface of salt silt baked by the sun and blistered by saline incrustations. It is varied only by the mirage of great tracts of dazzling white salt or extensive but shallow flashes of concentrated-brine. It is just possible that the river Luni has helped to raise the Rann of Cutch by salt it has carried during thousands of years.

The salinity of Rajasthan desert is wide-spread and extensive. The soil, surface and under ground waters in many parts of the region are more or less impregnated with saline substanee. The well-water in many parts of the desert are brackish.

CAUSES OF SALINITY

The origin of salinity has not yet been fully understood. The salt is supposed by some to have been formed from the felspathic rocks of the surrounding hill ranges by decomposition and weathering due to atmospheric factors, Sarin (152). This is washed down into the areas of depression by the rain and concentrated there. These form the saline lakes of the area due, therefore, to leaching action as mentioned above. Holland and Christie (1909) proposed a wind borne theory of the origin of salt in Rajasthan Desert. Each year large quantities of fine salt are brought by the action of wind from the saline concentration of the Rann of Cutch and deposited in the interior of Rajasthan and leached into the depresions and lakes by south west monsoon winds. The salt formed at different places varies in its chemical comositions from place to place and in all cases it is different from that obtained fram the Sea. Therefore wind borne theory has come under a severe criticism by Godbole (1952).

Auden (1952) raises some difficulties in supposing that the present salt lakes have any connection with the Mesozoic and Eocene Sea and considers that the Wind borne theory inspite of defects probably does account for much of the regional salinity in the ground water, as well, as lakes in western Rajasthan. Prof. N. N. Godbole's recent work on salt resources of Rajasthan shows that saline material is largely due to *regional leaching and concentration in LAND BASINS*. Various arguments have been given for and against these theories. There is need for a scientific investigation into the origin of salinity. It is an urgent problem connected with the formation, expansion and naturally arrest of the desert, Salinity is also a natural source of great economic importance. The problem is of national interest and should be investigated at an early date.

OTHER CAUSES OF THE ARIDITY OF THE REGION

The prevalance of the desert conditions of the area are also due to other reasons. The climate is of the north tropical desert with extremes of hot and cold weather. The mean daily temperature exceeds 92° F from May to July with the Maximum in May, Afternoon readings reach upto 120° F and coincide with the season of drought, Higher temperature have been recorded. There ere among the highest in the world. The mean minimum temperature is generally below 30° F; lower temperatures have been recorded. The soil temperatures which greatly influence the physiology of the plant life are higher in summer and lower in winter than the average air temperatures.

The rainfall is scanty, precarious and sporadic. In half of the area particularly the west and north west part of the desert, the rainfall is not more than a few inches and is very irregular. There is gradual improvement towards the south and south east. Humidity is low. The area is isolated from the neighbouring areas by crustal barriers. The subsoil water supply of the region is, therefore, very poor. Strong and hot winds blow during summer. These and other factors are very trying for the plants.

Salinity of the soil leads further to a physiological drought. There is water in the soil near the lakes and the Luni river bed but it is not available to the plants on account of the concentration of the dissolved salts. This is distinct from the physical drought when the soil is actually dry.

NATURE OF SALINITY

According to Sarin (1952) the salinity of the soil of different places varies in its nature and chemical composition. The salts generally found are Sodium chloride, Sodium carbonate, Sodium bicarbonate and Calcium sulphate. Only at Pachbhadra Magnesium sulphate is found, whereas magnesium salts are important constituents of Sea brine. The percentage of Sodium chloride to the rest of the salts is generally higher than found in the sea brine as shown in the table below:—

Table 1.

Composition of brine of different localities *(precent)*

	Dry Basis Sambhar	Didwana	Pachbhadra	Sea,
Calcium Carbonate	...	...	...	0.345
Calcium Sulphate	...	...	3.970	3.600
Sodium chloride	87.300	77.190	85.660	77.758
Sodium sulphate	8.650	20.650	...	...
Sodium carbonate	3.870	0.600	...	...
Sodium bicarbonate	...	1.560	...	...
Magnesium sulphate	...	...	9.440	4.377
Potassium chloride	0.129	...	...	2.465
Magnesium chloride	...	...	1.930	10.878
Magnesium bromide	0.051	...	...	0.217
Total	100.000	100.000	100.000	100.000

pH OF THE SOILS

The pH value of the soils shows that majority of the soils are slightly alkaline and the lowest pH of the soils studied has been found to be near 7.5. The pH of the soil in the Luni river area during the rainy season varies from 8 to 8.5 though it reaches 9.0 at lower depths. The soil is more alkaline during the winter season when pH reaches 9.0 to 9.5 as the salts are brought to the surface layers due to evaporation. During the rains there is less salt due to the leaching effect of the water so some plants come up on the fringes of the saline areas where the salt content is the lowest. In the Sambhar lake and in the central areas of the other lake the concentration of the dissolved salts is high and no angiospermic flora has been observed due to the physiological drought. Plant growth is adversely affected on saline soils as a consequence of the increase in osmotic pressure and the accompaying decrease in the physiological availability of water which results from an accumulation of neutral salts in the salt solution.

Growth is also restricted through the accumulation of toxic quantities of varions-ions within the plant. Low productivity on these soils is believed to result primarily from unfavourable physical conditions induced by their high content of exchangeable Sodium. Reviews of plant growth on saline and alkali soils have been published by Mugisted (1945) and Hayward and Wadleigh (1949). Blatter and Hallberg (1918-20) have mentioned a few halophytic species of the Desert area; *Chenopodium album* Linn, *Atriplex crassifolia* Mey, *Suaeda fruticosa* Forsk., *Haloxylon recurvum* Bunge, *H. salicornicum* Bunge, *H. multiflorum* Bunge, *Salsola foetida* Del., species of *Portulaca*.

Recently Biswad and Rao (1953) have listed halophyotic species of the Rajputana Desert.

Blatter, McCann and Sabnis (1929) have mentioned the following plants from the soils impregnated with salt, from the Indus Delta : *Suaeda fruticosa*, *S. nudiflora*, *S. monoica*, *Aeluropus villusus*. Agharkar (1952) has noted that *Chenopodiaceae* in general, *Anabasis Atriplex*, *Salsola* and other plants are found in salt localities.

Shanti Sarup and L. N. Vyas (1953) studied the salt plants occuring in Jodhpur Tehsil. Shanti Sarup and Kishan Dutt (1954) studied the halophytes of Luni river bed in relation to soil structure and composition and a detailed analysis of the saline soil plant communities has been recorded.

Tamarix dioica Roxb and *T. gallica* var *articulata* Wall are the only species which grow on these banks of saline depressions of Sambhar lake and Luni River bed. These present a dull, bluish appearance. At the blossoming season the scaly, thin branches are crowded with numerous pinkish flowers. The twigs of the plants may be covered with saline efflorescence. *Tamarix* also grows in association with *Calotropis*, *Zizyphus*, *Acacia arabica*, *Aerua*, *Salvadora*, and other plants. In the saline tracts a little away from the bank *Suaeda fruticosa* Forsk., species of *Cyperus*, *Pluchea lanceolata*, *Trianthema monogyna* and species characteristic of the sandy plains such as *Aerua tomentosa*, *Leptadenia spartium*, *Boerhavia diffusa*, *Farestia jacquemontia*, *Cleome Papillosa* are found. Annual species predominate. In the plains some areas are characterised by halophytic species such as *Suaeda fruticusa* Forsk., *Haloxylon recurvum* Bunge, *H. salicornicum* Bunge, *H. multiflorum* Bunge, *Salsola foetida* Del., *Atriplex crassifolia* Mey, and species of *Portulaca* and *Chenopodium.*

No zonation has been noted at any of the localities.

The dry saline situations are devoid of vegetation except that during the rains or after a shower of rain a few plants of the species mentioned above come up here and there.

These plants show special adaptations such as fleshy leaves and branches, thick epidermis, salt secreting glands fleshy guarded stomata, water bearing tissues etc.

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11

ECOLOGICAL STUDIES ON THE VEGETATION of JODHPUR TEHSIL

By

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INTRODUCTION

The Jodhpur Tehsil is almost the central area of the Jodhpur Division situated between latitude 26° to 27°N and Longitude 72.5° to 73.5°E with an area of nearly 2870 sq. miles. The Tehsil is surrounded towards the north-western and western regions by Phalodi, Sergarh and Pachpadra Tehsils. Towards the east and north-east Merta, Bilara and Nagour form the bounding Tehsils.

Among the boundary areas Phalodi and Shergarh situated towards North and North-west are characterized by vast areas with sand dunes. Towards the South East and East the Bilara and Pali Tehsils are traversed by several tributeries of the river Luni and are comparatively fertile.

Within the Jodhpur Tehsil itself the topography of the area is considerably varied. Most of the area consists of sandy plains while in the neighbourhood of Jodhpur and towards North-east region there are several discontinuous mountaineous chains This tectonic group of mountaineous chains are the upshoots of the Arawali ranges and do not reach a height of more than 1200'

Towards the north are situated several undulating plains with sand dunes of different sizes and they merge with the sand dune of Sergarh Phalodi areas. These plains of Jodhpur Tehsil are situated at the height of 700 to 800 ft. above the sea level but this is subjected to variations at different places within the region due to the uneven topography brought about by the sand dune in the surrounding areas and the mountains. The torrential flow of rain water cuts the soil in the plains and other areas, within the region and causes considerable distortion in the even surface of the area; as a result of this there are several ditches and ponds of temporary nature.

There are no natural tanks in the area. In neighbourhood of Jodhpur there are several water reservioirs or bunds situated within the hills, where the rain water collects. These forms the main source of water supply for irrigation and other purposes.

The Luni river bed is situated within a very short area of the Jodhpur Tehsil consisting of low plains with several elevations and depressions due to the sand and soil deposited by the running water but the depth of water in the river is considerably low during the major part of the year. The water is a little saline.

For studying the vegetation in different habitats the following areas of the Jodhpur Tehsil have been selected.

I. MOUNTAINEOUS AREAS.

1. Takhat Sagar Area :

This area is situated towards the west and this is a typical rocky area with a huge water reservior surrounded on all sides by hills. The whole area is characterized by two characteristic associations that of *Prosopis* and *Euphorbia*. There is however an abundance of species in the East and West. *Coldenia Procumbens* was found to grow abundantly only near the water fringe of the water reservior.

Nagadari :

This area is situated towards the north and is a raised mountaineous area near Mandore. At the top of the mountain is a water reservior from which water overflows in the form of a small stream.

Here water flows almost throughout the year and the vegetation here represents the influence of a microclimate in the areas which is generally arid or semiarid and along this stream grow characteristic hydrophytic or semi hydrophytic plant species which include *Hygrophylla, Cyperus, Ammaniabacifera, Sesbania* etc. The most dominate component of the vegetation in this region is *Cryptostegia grandiflora*.

Massuria :

This area situated towards the west, is one of the localities at which rocks are quarried and broken into convenient sizes for construction purposes; as such this area is subjected to influence of man and his rock boring implements. The effect of grazing animals also is comparatively much in this area. At the base of Massuria hills are situated sandy plains.

II. MIXED MOUNTAIN AND PLAIN AREAS.

1. Balsamad :

This area is situated towards north of Jodhpur and there is a huge reservior surrounded by hills on all sides.

2. Sursagar :

This area is situated towards the Nor h-West direction. The rocky plateau in this area dows not support practically any vegetation due to biotic disturbances as in Massuria area. The surrounding sandy plains are characterized by a few shurbs the frequency of which is very rare.

3. Akheraj ji's Tank :

It is situated towards the west and illustrates the mixed nature of rock and plain vegetation to a markable extent. The road leading to the area supports on each side associations of *Leptadenia* and *Aerva*, *Tecomella* and *Gymnosporia*. A few yards ahead comes up the mixed association of *Gymnosporia, Euphorbia, Acacia* and *Ephedra*. Further ahead the sandy plains disappear and the area is characterized by species *Euphorbia Grewia* and *Acacias*.

4. Chandpole Gate area :

It is situated on the North. In the north oi this area are several small water reserviours. The Southern region joins with the Akhey Raj Ji's Tank area, already described. On the eastern side stands the old fort while towards the west are rocky areas which are cut out from ordinary plain areas. Poor vegetation towards the east and west is due to the Biotic disturbances.

III PLAIN AREAS.

1. Bakhat Sagar—

It is situated towards the West just out side the Jodhpur city. This was formerly a depressed area where rain water collected. It is bounded by raised hillock of sandy loam towards the south and east. The depressed area is now completely covered by the municipal debris and a small low land stream of waste water drains of this city runs through the centre of the area.

2. Sewage Farm area—

Situated towards south. This area is fed with waste water rich in nitrogenous wasta materials.

IV. SAND DUNE AREA.

Massuria and Aerodrome Sand dunes.

These areas are characterized by sandy soils with sand dunes of different heights. The aerodrome area is situated towards the south of city while Massuria is towards west on way to Takhatsagar.

V. SALINE AREA.

Luni river bed area—

Luni is the most important river of Rajputana and it is 25 miles away in the South-west of Jodhpur. The depth of the water in this river is low during the major part of the year. Salinity of water is not much. The river dries up and the sandy river bed remains exposed for the most part of the year.

II. Climate—

The climate in the investigated region is typical of the other semi arid regions of Rajputana. It is characterized by low annual rainfall, the annual rainfall is usually below 15″. Most of the rains occur during July to September. Another characteristic feature of the climate of this area is the great extremes of temperature. There is considerable difference between the winter and summer temperatures. The low precipitation and the high temperature result in a dry climate which is characterized by a low relative humidity. The relative humidity during the cold season is 50–60% in the morning while in the afternoon hours it reaches to a value between 25 to 35%. In hot months it reaches to a value between 10 to 60%. The relative humidity markedly increases during the monsoon seasons. Thus the low values of relative humidity in the atmosphere are unfavourable since they enhance transpiration in an area which is already at a dis-advantage by low precipitation.

The above features are further aggravated by high wind velocity with dust and thunder storms during the different parts of the year resulting in the erosion of soil which greatly affect the herbaceous vegetation growing in the area.

Records of dew formation are lacking from Rajasthan. But according to Ramdas (1952) since the nights for a large number of days in the year are clear and atmospheric air is fairly humid there may be possibilities of dew formations.

Table No. 1

TEMPERATURES.

Months.	Temp.		Mean Temp. for the last 10 years.	
	Max.	Min.	Max.	Min.
June '52.	109	71	104.6	82.7
July '52.	103	62	97.7	80.5
Aug. '52.	98	73	93.3	78.0
Sept. '52.	104	72	94.9	75.5
Oct. '52.	105	57	96.9	67.5
Nov. '52.	96	53	89.7	58.5
Dec. '52.	86.1	45.3	79.7	52.7
Jan. '53.	85.5	39	76.1	49.6
Feb. '53.	91.5	46	80.0	53.0
March '53.	93.5	42	91.1	62.9

Table No. 2

Rainfall.

Months.	Rainfall	Mean Rainfall during last 10 years.
May, '52	0.0"	0.41"
June, 52	.8"	1.42"
July, '52	11.25"	3.97"
Aug., '52	5.1"	4.18"
Sept., '52	0.0"	2.42"
Oct., '52	0.0"	.32"
Nov., '52	0.0"	.11"
Dec., '52	0.0"	.11"
Jan., '52	0.0"	.15"
Feb., '53	0.0"	.24"
March '53	0,0"	.11"
Total for year	17.15"	14 21"

Table No. 3

Months.	Relative humidity		Mean Relative humidity during last 10 years.	
	Max.	Min.	Max.	Min.
June '52	83%	13%	63%	34%
July '52	96%	31%	73%	46%
Aug. '52	98%	35%	52%	50%
Sept. '52	78%	21%	76%	40%
Oct. '52	49%	8%	54%	16%
Nov. '52	59%	11%	45%	18%
Dec. '52	62%	12%	53%	22%
Jan. '53	96%	11%	50%	22%
Feb. '53	85%	15%	50%	21%
March '53	73%	12%	39%	17%

III. GEOLOGY AND SOILS.

Geology and history of Rajputana presents interesting features. According to Krishnan (1952) it is reasonable to state that Rajputana was not arid in the Pleistocene and Subeocene periods. Aridity seems to have developed since the last 2000 years. Part of Western Rajputana was undoubtedly occupied by a sea during the Jurrasic, Cretaceous and Eocene. This area was uplifted into dry land most probably during the upper Teritary. The occurance of Gypsum and other salts in Jodhpur and Bikaner hill ranges is an indication of this fact.

Hora (1952) has shown the occurence of six species of fish in the Aravalis and they are typical fauna of peninsular India. According to him the Aravali range underwent great change during the last Himalyan movement and a major part of it was submerged below the sand. Archeological evidence shows that Rajasthan had been inhabited during the prehistorical period and also the Western and Northern parts were not so arid as now since the habitation belts were much wider during the previous Archeological periods.

In considering the origin of salt in Lakes and gound water of Western Rajputana from the geological and chemical point of view Auden (1952) points out that the Rajasthan salt lakes cannot be said to have any connection with the Mesozoic and Eocene seas. The lack of calcium and magnesium salts in Rajasthan salt lakes can be explained if Rajasthan had been formerly connected with sea. Gypsum, no doubt, occurs in Rajasthan and according to Auden this is pssibly derived from the underlying primary Vindhyan Gypsum. The wind transport theory of salt by Holland and Christie, thus appear to be an important fact in affecting the annual increase of salt in Rajasthan but Godbole (1952) argues that the chemical composition of salt lakes in Rajasthan should not differ if they are fed by perrenial wind transport on the basis of the data he could collect. Godbole rules out the wihd borne theory of salt and favours the connection to sea during the prehistoric times.

In a geophysical exploration in the arid tract of Rajasthan, Rao and Negi point out that the underground water is brakish over a wide area submerged in Bikaner division while in Jodhpur some patches of drinkable water could be recognised. The mineral resources as pointed out by Sethi reveal that Rajputana has formations dating back to Eocene. The geological succession in Western Rajputana according to Ghosh (1952) proceed from the Archean to recent and subrecent through Purana, Upper Carboniferous, Mesozoic, Eocene and Post Eocene,

THE CHIEF NATURAL SOILS ARE :

1. **Mattyali** :—is clayey loam of 3 kinds namely (a) *Rati* (b) *Pili* and (c) *Kali* and covers about 18% of cultivated area. It does not need frequent manuring but is stiff. It produces wheat, Gram and cotton.

2. **Bhuri** :—Most prevailing occupying over 58% of the cultivated area and requires but moderate rains. It has lesser clay and is easily amenable to plough.

3. **Retli** :—Is fine grained and sandy without clay and forms about 19% of the cultivated area. This when found in a depression it is called "dehri" and when on hillocks or mounds it is called "*dhora*".

4. **Magra** :—Is hard soil containing considerable quantity of stone and pebbles. It is found generally near the slopes of the hills and occupies about 4% of the cultivated area.

A close survey of the physical and chemical nature of the soil in the different investigated areas reveals the following facts :

1. In most of the areas the soil is sandy and loose with very little humus content.

2. The soils are fairly rich in carbonates and chlorides.

3. The water content of the soil is usually low and the amount of water contents gradually increases from the surface to the deeper layers.

4. Nitrates are usually deficient in the soils ; only in certain areas where there is large amount of putrefying material appreciable amounts of nitrates have been recorded.

5. Most of the soils are rich in exchangeable bases such as magnesium, calcium and potassium.

6. The pH. value of the soil in most of the areas is on the alkaline side which also proves that soils are rich in exchangeable bases.

7. As a result of dessication it has been generally observed that the water content, and the nitrate contents of the soil decreases. The base exchange capacity and pH. are almost unaffected. The alkalinity of soil increases.

8. The humus contents in the soil has been found to very from season to season, which is largest during the winter months. In the following hot dry season very little humus has been observed in the soils and this may be due to the fact that blowing winds might carry away the accumulated humus of the previous season.

The above facts reveal that the main disturbing factors in the soil are the sandy nature, and the low water content. The soils are not deficient in the necessary minerals for plant growth.

BIOTIC FACTORS.

The Biotic factors, as they are usually called, primarily include man and other animals. The influence of man upon the vegetation of Rajasthan, in general, has been very adverse. The geological events resulted in warmer and drier climate in the area and the people inhabiting this area had taken to Nomadic life by about 1000 B. C. Vast areas of forest were used for fire wood and other domestic purposes as a result of which the vegetation had decreased and reached the present status. Herds of grazing animals kept by nomadic trives used up the vegetation where ever it existed. These features which were prevalent in the past still continue in many parts of the area. Man is used to felling of the trees and lopping the tops of the branches for his domestic purposes; even the ground vegetation is scraped by him for fuel purposes. Sometimes even big trees are uprooted and smaller plants are trempled without any sense of their importance and the effect of man is thus very adverse in allowing the vegetation to develop into climax.

In addition to the interferance by man grazing animals like sheep, goats, cattle, camels, deer, rabbits and other cause considerable havoc to the vegetation. The rabbits, squirrels, rats, and peacocks are very fond of tender plants and pick up the plants even in the seedling stage and use them up as their diet. Thus even in the sprouting phase vegetation is considerably affected.

There are numberous insects found in Rajasthan but amongst them the desert locust is the only pest which effectively enhances the spread of the desert. This pest destroys the annuals and perennials both in the hopper and adult stages. The locust devours the leaf and even the bark of the host plants leaving only the woody portion behind. This ultimately results in the death of the adult plant.

Rats dig holes in the soil for their habitation and make the soil loose thus affecting the water retaining capacity of the soil.

Ants and white ants which live beneath the soil and by boring through the soil crevices they render it very loose. These and the birds tenaciously feed upon the seeds of the plant species left in the soil and reduce the number of germinating seeds in the next favourable season.

In addition to the animal pests there are number of plants pests which effect the vegetation during different parts of the year. A number of fungus pests have been observed both on cultivated and wild species during the course of this investigation.

V. FLORISTIC COMPOSITION

The present Ecological survey reveals several interesting features.

A characteristic feature of the rock vegetation are the associations of *Euphorbia* which grow even on barren rocks. They appear as sentinels of vegetation on rocks in the neighbourhood of Jodhpur. The distribution of these *Euphorbia* associations does not present any zonational aspect to the rock vegetation since they are present at all levels even on mixed sand and rock areas.

Some of the other common plants belonging to this group include *Gymnosporia emarginata*, *Zizyphus rugosa*, *Anogeissus pendula*, several species of *Acacia* and *Cordia*.

The above trees and shrubs are suplemented by large number of annual and biennial species during the rainy season. These include species of *Tephrosia*, *Abutilon*, *Sida*, *Peristrophe*, *Barleria*, *Corchorus*, *Trianthema*, *Heliotropium*, *Tribullus*, *Pupalia*, *Commelina*, and a number of grasses most of which include species of *Cenchrus*, *Andropogon*, *Eragrostis*, *Aristida* and *Chloris*.

This different status in vegetation of hills is mainly because of the collection and retention of rainwater in several large or small basins during the rainy season. Even the vegetation of the hilly areas show adaptation for the arid and semiarid conditions which must be due to the fact that many of the plant species represented on the hills are those which have migrated from the plain areas.

The plains show a vegetation much different to rocks. Different types of plain areas recognised in the investigated areas are cultivated fields, areas with a admixture of soil and gravel, few regions fed by waste water etc.

The perennial species within these areas include mainly *Capparis aphylla*, *Prosopis spicigera*, *Salvadora*, *Calotropis procera*, several species of *Acacia*, *Leptadenia Spartium* and nimbers of cultivated plants like *Ficus* and *Melia* etc.

The rainy season vegetation in the plains in characterised by the development of number of annuals like *Gynandropsis*, *Tephrosia*, *Mollugo*, *Trianthema*, *Solanum*, *Argemone*, *Boerhaavia* *Cleome*, *Leucas*, *Sida*, *Polygonum*, *Potentilla*, *Fasctia*, and variety of grasses.

In plains ephemeral vegetation gererally does not continue beyond the months of October and November except in a few isolated patches where pockets of collected water are present.

The plant species in consolidating the soil against the wind erosion are different in different areas due to different nature of the sand-dunes. Some of the sandunes have been seen to be very much disturbed by the action of wind. Such localities support plants like *Leptadenia*, *Crotolaria*, *Aerua*, and *Calatropis* along with the species of *Indigofera* and some grasses. In some places pure associations of *Caloprepsis* have been noted.

In well developed sandunes *Calligonum polygonoides* was seen to be dominant along with *Aerua*, *Ephedra foliata*, *Mimosa hamata*, *Zizyphus rotundifolia* etc.

The vegetation of Saline Luni River bed area is not conspicuously different from that of plains as salinity is not so high. The river bed usually dries up and the sandy bed remains exposed for most part of the year. There is no other species except Tamarix, for miles and miles along the river bed. This is also associated by *Suaeda*, *Cyperus*, *Pluchea lanceolata* and *Fimbristylis*, Some of the species growing on the bank characterstic of sandy plains are *Aerua*, *Leptadenia*, *Boerhaavia*, *Indigofera* and *Mimosa*.

The sandy banks lead to the gravel plains. The vegetation in this area is chracterized by *Aristolochia*, *Mollugo Anticharis*; *Boerhaavia* etc.

PLANT ASSOCIATIONS

Several ecological plant associations recognized growing in the different situations such as the hills, (ii) hill and plains (iii) Loamy plains (iv) Sandy plains (v) Sand dunes (vi) Luni river bed (vii) mountain streams (viii) Aquatic associations etc. are as follows;—

(A) PLANT ASSOCIATIONS ON HILLS.

1. **Euphorbia royleana** Linn *d* pure association.

2. **Euphorbia-zizyphus association.**

Euphorbia royleana Linn	*d*	*Zizyphus rugosa* Lamak	*co. d*
Sericostoma brevistigma Stocks.		*Asparagus racemosus* Willd	*r*
Achyranthes aspera Linn	*a*	*Grewia asiatica* Linn	*c*
Capparis aphylla Roth.	*c*	*Cleome viscosa* Linn	*a*
Cynondon dactylon Pers.	*a*	*Cryptostegia grandiflora*	*a*

3. Opuntia-Euphorbia association.

Opuntia dillenii Har.	d	*Euphorbia royleana* Linn	d
Grewia populifolia Linn	co.d	*Cenchrus biflorus* Sweet	a
Achyranthes aspera Linn	c	*Evolvulus alsinoides* Schweinf	a

4. Grewia-Asparagus association.

Grewia populifolia Linn	d	*Asparagus racemosus* Willd	a
Abutilon indicum Sweet	co.d	*Tephrosia purpurea* Pers	co.d
Anogeissus pendula Linn	c	*Euphorbia royleana* Linn	a
Barleria cristata Linn	a	*Tecomella undulata* Seem	c
Achyranthes aspera Linn	a	*Euphorbia hirta* Linn	a
Phyllanthus madaraspatensis Linn	c	*Justicia procumbens* Houst.	r
Tridax procumbens Linn	a	*Vernonia abyssinica* Schreb	c
Sporobolus orientalis R.Br.	o	*Chloris virgata* Swartz	a
Eragrostis cilliaris Host	a	*Eleusine indica* Gaertn	a

(B) PLANT ASSOCIATIONS ON MIXED HILL AND PLAIN.

1. Euphorbia-Prosopis association.

Euphorbia royleana Linn	d	*Prosopis juliflora* Dc.	co.d
Capparis aphylla Roth	co.d	*Cocculus villosus* D. C.	c
Sida cordiflia Linn	c	*Abutilon indicum* C. Don.	c
Abutilon asiaticum Don.	c	*Corchorus antichorus* Raevschel	c
Corchorus acutangulus Linn	c	*Tephrosia purpurea* Pers.	a
Trianthema monogyna Linn	a	*Pentatropis cynanchoides* R.br.	a
Heliotropium zeylanicum Lam	c	*Pupalia lappacea* Juss	a
Achyranthes aspera Linn	a	*Aerva tomentosa* Forsk	c
		Andropogon annulatus Forsk	a

2. Euphorbia-Capparis Association.

Euphorbia royleana Linn	d	*Capparis aphyla* Roth	co. d
Gymnosporia montana Benth	co. d	*Ephedra foliata* Boiss	a
Boarhaavia diffusa Linn	a	*Boerhavia repanda* Linn	a
Achyranthes aspera Linn	c	*Abutilon indicum* Sweet	c
Polygala erioptera D. C.	a	*Abutilon fruticosum* Gull & Perr.	a
Sida spinosa Linn	c	*Corchorus tridens* Linn	c

Indigofera tinctoria Forsk	c	*Cocculus cebatha* D. c.	a
		Evolvulus alsinoides Schweinf.	a
Tridax procumbens Linn	c	*Andropogon faveolatus* Dal.	a
Cenchrus biflorus Roxb.	a	*Chloris barbata* Trin	a
Digitaria longiflora Heist	a		

(C) PLANT ASSOCIATIONS ON PLAINS.

1. Gymnosporia-Capparis Association.

Gymnosporia montana Benth	d	*Capparis aphylla* Roth	co. d
Acacia rupestris Stocks	co. d	*Ephedra foliata* Boiss	a
Boerhavia grandiflora Rich	c	*Crotalaria Burhia* Dill	c
Leptadenia spartium Wight	c	*Aristida paradisea* Retz.	a

2. Capparis-Leptadenia association.

Capparis aphylla Roth	d	*Leptadenia spartium* Wight	co. d
Gymnosporia montana Benth	co. d	*Aerva tomentosa* Frosk	c
Zizyphus rugosa	a	*Crotalaria burhia* Dill	c
Boerhavia diffusa Linn	a	*Tephrosia purpurea* Pers	a
Gynandropsis pentaphylla D. c.	a	*Digera arvensis* Forsk.	a
Leucas aspera Spr.	c	*Setaria glauca* Beauv.	a

3. Tephrosia-Gvnandropsis Association.

Tephrosia purpurea Pers.	d	*Gynandropsis pentaphylla* D. c.	co d
Tribulus terrestris Linn	a	*Euphorbia microphylla* Linn	a
Cenchrus biflorus Roth	a	*Chloris barbata* Trin & Swartz	a

4. Solanum-Argemone Association.

Solanum Xanthocarpum Dun	d	*Argemone mexicana* Linn	co. d
Solanum indicum Tourn	r	*Gynandropsis Pentaphylla* D. c.	co. d

(D) PLANT ASSOCIATIONS ON SAND DUNES.

1. Caparis–Calligonum association.

Capparis aphylla Roth	d	*Calligonum polygonoides* Linn	co d
Leptadenia spartium Wight	a	*Calotropis procera* R. Br,	c
Chloris barbata Trink & Swartz	a	*Sida cordifolia* Linn	a

2. Crotalaria-Aerva Association.

Crotalaria burhia Dill	d	*Aerva tomentosa* Frosk	co. d
Polygala abyssinica R. Br.	a	*Cenchrus biflorus* Roxb.	[illegible]
Mollugo hirta Thumb	c	*Tephrosia purpurea* Pers.	a
Trianthema monogyna Linn	c		

3. Calotropis-Leptadenia Association.

Calotropis procera Rbr.	d	*Leptadenia spartium* Witht	co d
Crotalaria burhia Dill	a	*Aerva tomantosa* Forsk	c
Sida cordifolia Linn	c	*Achyranthes aspera* Linn	c
Cynodon dactylon Pers.	a		

4. Gymnosporia-Ephedra Association.

Gymnosporia montana Benth	d	*Ephedra foliata* Boiss	c
Calotropis procera R. Br.	a	*Mollugo nudicaulis* Lam.	a
Mollugo cerviana Seringe	a	*Spermacocce calyptera* Dcne	c
Coccinia indica Wind & A	c	*Commelina bengalensis* Hask	c
Tribulus terrestris Linn	a	*Achyranthes aspera* Linn	a
Abutilon indicum Sweet	c	*Eleusine aegyptica* Desf	c
Cenchrus biflorus Roxb	a	*Andropogon faveolatus* Rel	a
Eragrostis unioloides Nees	a		

(E) PLANT ASSOCIATIONS ON MOIST ROCK STREAM.

1. Cryptostegia-Sesbania Association.

Cryptostegia grandiflora Br.	*d*	*Sesbania aegyptiaca* Pers	c
Convolvulus arvensis Linn	c	*Morinda indica* Linn	c
Boerhavia diffusa Linn	c	*Cyperus compressus* Linn	c
Heliotropium ovalifolium Forsk.	*a*	*Achyranthes aspera* Linn	*a*
Trianthema monogyna Linn	c	*Commelina bengalensis* Hassr	*r*
Chloris barbata Sw.	c	*Eleusine aegyptica* Desf	*a*

2. II Hygrophylla Sesbania Association.

Hygrophylla longifolia R. Br.	*d*	*Sesbania aegyptiaca* Pers.	c
Amarantus spinosus Linn	c	*Boerhavia diffusa* Linn	*a*
Eclipta erecta Linn	c	*Polygonum plebejum* Linn	c
Mullugo trigonelloides Linn	*a*	*Argemone mexicana* Linn	c
Cynodon dactylon Pers.	*a*	*Chloris barbata Trin* & Swartz	*a*

(F) PLANT ASSOCIATION ON SALINE RIVER BED.

1. Tamarix Association.

Tamarix dioica Roxb.	*d*	*Tamarix gallica* Vahl	*co. d*
Pluchea lanceolata C. Bei.	*a*	*Farsetia jacquemonti* Hook	c
Suaeda fruticosa Forsk	*a*	*Kylinga triceps* Rottb	c

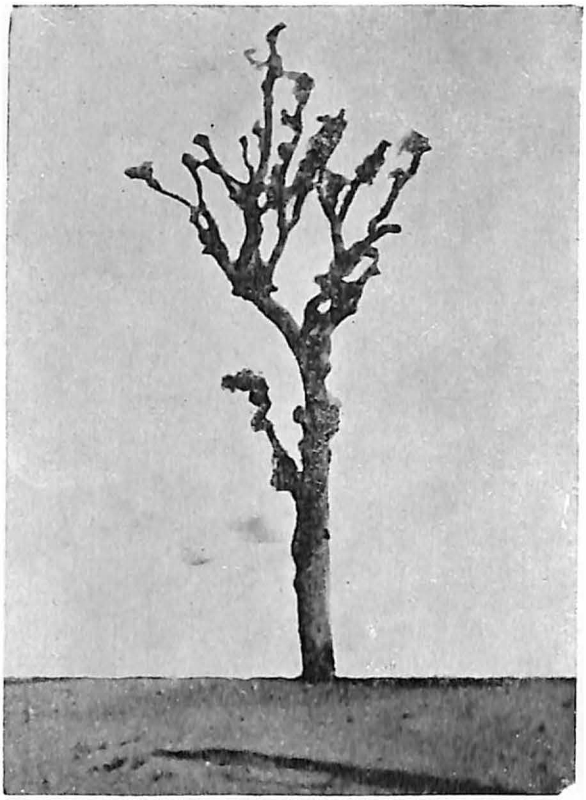
2. Tamarix-Pluchea Association.

Tamarix dioca Roxb.	*co. d*	*Pluchea lanceolata* C. B. Cl.	*d*
Farsetia jacquemontii Hook	*a*	*Cleome papillosa* Stand	c

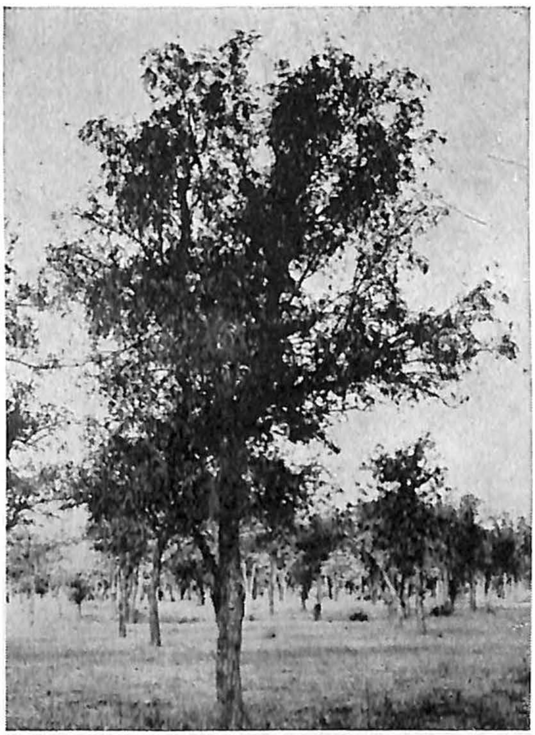
(G) PLANT ASSOCIATION ON LOAMY DRIED UP SOILS,

1. Polygonum Potentilla Association.

Polygonum plebeium Linn	*d*	*Potentilla desertorum* Linn	*co. d*
Marsilea quadrifolia Linn	*a*	*Heliotropium undulata* Vahl	*a*
Eclipta erecta Linn	c	*Amarantus viridis* Linn	c
Cleome viscosa Linn	*a*	*Boerhaavia diffusa* Linn	c
Gynandropsis pentaphylla Dc.	c		

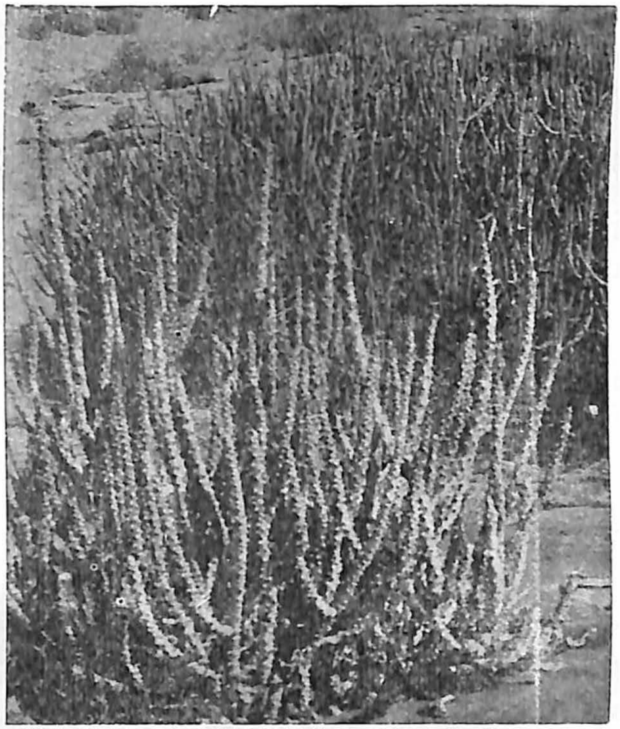


Prosopis Sp. cigera plant badly mutilated.



Prosopis Spicigera

A big 'tree' of *Cappiris aphylla* at Bhikam Khor.



Euphorbia Neriifolia Linn on rocks *in* Jodhpur.

2. **Coldenia Heliotropium Association.**

Coldenia procumbens Linn	*d*	*Heliotropium indicum* Linn	*a*
Tephrosia purpurea Pers	*a*	*Boerhavia diffusa* Linn	*c*
Alysicarpus vaginalis Neck	*c*	*Lippia nodiflora* Rich	*a*
Tribulus terrestris Linn	*c*	*Heliotropium undulatum* Vahl	*a*
Eclipta erecta Linn	*c*	*Eleusine aegyptiaa* Geertn	*a*
Portulaca grandiflora Linn	*c*		

(H) AQUATIC ASSOCIATION.

1. **Eichornia-Potamogeton Association.**

Eichornia Kunth	*d*	*Potamogeton crispus* Linn	*co. d*
Lemna polyrrhiza Linn	*c*	*Microcystis* Sps.	*a*
Spirogyra Sps.	*a*	*Oedogonium* Sps.	*a*
Wolffia arrhiza Winm	*r*		

2. **Hydrilla-Vallisneria Association**

Hydrilla verticillata Casp.	*d*		
Vallisneria spiralis Linn	*co. d*	*Ceratophyllum demersum*	*a*
Chara Sps.	*a*	*Nitella* Sps.	*d*

VI. ECOLOGICAL STATUS

It is interesting to trace the succession of plant communities in the aforesaid localities of different Ecological set up. For the sake of understanding successional relation-ship between the different plant communities growing in the area, we can conveniently divide the area into the following Ecological areas:—

1. Moist rock streams.
2. Mixed hill and plain areas.
3. Hard loamy plains.
4. Sandy plains.
5. Sand dunes.
6. Saline river bed.
7. Submerged and free floating aquatic associations.
8. Loamy dried up banks of water reserviors.
9. Dry Hills.

The chart represents the successional and climax relationships of the vegetation of the different ecological areas recognized in the course of this investigation.

The plant associations that grow in sandy plain areas may be taken to represent the starting point in the development of the vegetation. Starting from this there is a continuous stream of climax development culminating in the plant associations that grow in moist rocky streams areas and their neighbourhood, passing through the associations on hard loamy plains and mixed hill and plain areas. The vegetation in the sandy plains is subjected to two distinct disclimaxes-one of them resulting due to the shifting of sand by wind. This type of disclimax results in the scanty vegetation that is often seen in sand dune areas. The other type of disclimax is of a physiological nature brought about by the saline flowing waters of the river Luni and this type of disclimax is represented in the vegetation that we get along the saline river bed of Luni. There is another disclimax in operation in this area resulting in the vegetation characteristically met within the dry hills, this type of disclimax seems to have developed from the vegetation on the mixed hills and plains due to the combined effect of several climatic factors such as wind and drianage of the soil by rain waters.

The aquatic vegetation is mainly represented by the submerged and free floting plant associations that we get in the artificial water reservoirs in the hill valleys. This piece of vegatation develops into the climax type met within the dry hills passing through vegetational areas represented by the dried up loamy banks of the water reserviors.

The pioneer sps. in consolidating the soil in the sandy plains are represented by a variety of perennial shrubs and a number of annuals. The characteristic shrub sps. are *Capparis aphylla, Calotropis Procera, Acacia leucohylum, Prosopis spicigera* and the introduced *Prosopis Juliflora.* The rainy season annuals include *Tephrosia* a number of grasses and a variety of other sps. As the soil of the sandy plains become a little loamy due to the accumulation of humus and retantion of more water, more species are supported in the loamy plains and the most important characteristic additions over the previous area include plant associations like those of *Aristolochia, Echinops, Capparis, Salvadora, Euphorbia* and others. Further increase in species and plant associations is represented in the mixed hill and plain areas which support associations of *Euphorbia-Prosopis*, *Euphorbia Capparis*, *Gymnosporia Capparis* etc. The culmination in the climax represented for this region is met with in the moist rock stream areas where we can see the growth of an almost tropical forest.

The disclimax that results on the hill areas is represented by discontinuous associations of *Euphorbia* and *Euphorbia* alone for several miles. Just as *Capparis* and *Prosopis* seem to be pioneer species in the sandy plains, the Euphorbias appear to be pioneer on rocks.

The disclimax resulting in the sand dune vegetation is represented by plant associations of *Capparis-Calligonam*. *Gaymnosporia-Ephedra*, *Calotropis-Leptandenia* etc. The presence of *Capparis* and *Leptadenia* in several sand dune areas clearly indicates that it must have been derived as a disclimax from the plant associations growing in the sandy plains.

An ecological survey of the vegetation in the present investigated area reveals, that it is to a large extent controlled by the various ecological factors; the effect of the climatic and the biotic factors is more conspicuous than that of the edaphic. By the recent symposium on the Rajputana desert several authors have pointed on the uniformity of climate, existing in the region for last several years. The inclucnce of the biotic factor is changing the nature of the soil as well as climate. The above facts are of extreme significance in evaluating the status of the present vegetation and the methods which can be adopted to improve the deteriorating conditions of Indian desert.

In the present investigation the vegetation has been analysed at different habitat situations and a critical survey of the facts noted shows that there is a tendency for development of tropical forest type of vegetation in different areas where the water supply is in abundance. The presence of more plant species in natural or artificial troughs or basins even in the plains clearly reveals that water is an important factor in deciding the richness as well as the variety of the plant species. The existance of little microclimax in a few regions of the investigated area strongly supports the above conclusions.

The occurence of water table at a depth of more than 100 feet in many parts of Rajasthan along with the high mineralisation of water is a great drawback for the development of proper vegetation in the area.

There are several small plants associations that grow in the area of rainy season which are composed of a large number of foreign species. The above fact reveals that the soil can support quite a good number of introduced species provided water is made available.

Most of the rainy season annuals complete their life by the time the winter season sets in when a low water content prevails in the soil. At the foots of the hills and certain artificial ditches and troughs the rainy season annuals continue to grow even during the winter season. This fact again shows that the water is an important factor in successful colonization and establishment of plant species.

Most of the plant species that grow in the area are annuals and the lack of considerable number of perenial species is a great draw back in the existing vegetation. The perennial habit can be induced provided the water table in the soil is not affected much. This fact again reveals that water is a potent factor.

Considering the above aspects it is but logical to conclude that the vegetation of the present area has the potentialities of development into a climax of thorn forest but the main important drawback which retards the development of vegetation is the low water table of the soil.

SUCCESSION OF PLANT COMMUNITIES.

```
          Moist rock stream
              ↑
(Climax)      |
              |
          Mixed Hill and Plain ——→Dry hills
              ↑                       ↑
(Climax       |                       |        (Disclimax
              |                       |
          Hard loamy plains        Loamy dried up band
              ↑                          ↑
(Climax       |              (Climax)    |
              |          (Disclimax)    Aquatic
          Sandy plains  ————————→Saline river bed
              |          (Disclimax)
              ↓
          Sand dunes,
```

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PLANT ECOLOGY OF THE INDIAN DESERT, IN RETROSPECT AND PROSPECT.

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The planning Commission in its First Five Year Plan devoted a paragraph on the extension of the desert and its encroachment upon the fertile lands. Since then considerable interest has been aroused in the Desert and its reclamation. A review of the plant ecological work done, would be of interest and value from different points of view. Such studies would help in providing a protective vegetable cover for the loose sand.

The collection and study of the plants of Rajputana can be traced from the year 1852, when Mr. and Mrs. Allen, G. L) published a book "*The views and flowers f. om Gujrat and Rajpotana,*" which contained nearly thirteen coloured plates. But Allen's work is only a botanical curiosity since the descriptions of most of the plants are not on scientific lines. Moreover the plants included are generally trees from the hilly areas of Rajasthan and Gujrat. Very little information, if any, is given relating to the Desert plants.

Jacquemont, travelled through Delhi, Ajmer and Neemach etc. and his observations were recorded in the '*Journals of Jacquemont*' published posthumously by the French Government. They have hardly any reference to the plants of Rajputana.

William Griffith, a Surgeon in the Honourable East India-Company's Madras establishment, had an extensive knowledge and varied interest in different branches of Indian Botany. He traversed the upper parts of Sind on his way to Afganistan, and recorded in his private journals and literary notes "*The common Desert plants of Sind and Rajputana*", which he came across. Vast accumulations of his notes and manuscripts were posthumously published in nine volumes under the editorship of Dr. Mc Ciellànd during the middle of the 19th Century.

According to Hooker and Thomson (1855) Major Vicary published a list of some of the desert plants mostly from the province of Sind in the Journal of the Asiatic Society. The year and the place of publication has not been mentioned.

We are indebted to Dr. Stocks, for a knowledge of some of the characteristic desert plants although all of them are from the province of Sind.

Hooker and Thomson (1855) in their famous *Introductory Essay in Flora Indica*, observe that about nine tenth of the vegetation of Sind and Rajputana Desert are indigenous to Africa, out of which at least one-half is Egyptian. With these, there are considerable European species also. Very few are Eastern in origin, The flora of the desert of Jaisalmer resembels that of South Punjab, which also is a part of the Indian Desert. According to him the vegetation of the plains of Marwar, which are continuous with the great sandy desert stretching in the west to the Indus, is not known in details.

George King, M B. who was an Assistnnt Surgeon attached to the Marwar Agency and later went to the Saharanpur Botanical Gardens, collected some data on the '*Famine plants of Marwar*' and published them in the year 1869 in the *Proceedings of Asiatic Society of Bengal*. He gave local names of these plants but the botanical names of most of them have now been found to be incorrect. Sir George King, F. R. S , later the Director of Royal Botanic Gardens, Calcutta published in 1879, an excellent paper in the Indian Forester, "*The sketch of the flora of Rajputana*". It remained for many years the only true scientific record of the plants of Rajputana including the Desert areas.

The most useful reference about the plants of Indian Desert can be traced in an "*Introductory note to Jodhpur and Jaisalmer, trees and plants*" This is an anonymous list, neither the name of the author, nor the publisher, nor any date, whatsoever is given. Blatter and Hallberg (1917-1921) ascribe this note to Miss Macadam She published another list "*A list of trees and plants of Mount Abu*", which was pnblished at Jodhpur. The general arrangement of the pamphlet and the treatment of the subject in these two publications are similar. Miss Macdam has given vernacular and Botanical names, together with their utility and short descriptive notes of trees and plants found during the month of November to February in the neighbourhood of Jodhpur and Balotra and a march from the later place to Jaisalmer where she halted for ten days in the month of December. About 140 species have been ennumerated in this list. Adams (1895) gives "*A lis of the plants of Jodhpur, J.is.lmer and Mount Abu*", by Miss Macadam which is probably synthesized from the above two lists of the same author. In his wonderful medicotopographical and general account of Jodhpur, Jaisalmer and Sirohi States, *The Western Rajputana State Agency* Adams (1895) gave a chapter (404-422) on '*the forests and flora*' of the areas, listing 48 species of trees and plants and 5 common grasses of desert areas. It is mostly based on Miss Macadam's list and confirmed by his own observations.

Sir J. D. Hooker (1907) wrote a chapter on Botany for the Imperial Gazetteer of India Vo. I. The notes about the plants of Rajputana have been added after King (1874).

The most remarkable work on the plants of tho Indian Desert was published in the years (1917-21 , by Fr. Blatter S, J., and his worthy associate Prof. F. Hallberg. Reverend father Ethelbert Blatter was Swiss by birth who came in India in the year 1903 as Prof. of Biology in the St Xavier's College, Bombay. Immediately on his return from the continent in 1915 he was attracted by the vegetation of the Indian Desert, because, in his own words "The vast desert of N. Africa, Arabia, Central Asia and even of the new world have attracted the attention of many Botanists but the Indian Desert has been sadly neglected". He therefore, in October and November 1917 accompanied by Prof. F. Hallberg and two of his students Messers T. S. Sabnis and D. B. Bulsara came to Jodhpure and the party visited Jodhpur, Bhikamkor, Phalodi, Jaisalmer. Bap, Vinjorai, Barmer and Balotra etc. which are the earily accesssible parts of the Indian Desert in west. The botanical, geological and meteorological results of this important tour were published in the *Journals of Bombay Natural History Society*, of which Father Blatter was Editor for a number of years. This '*Flora of the Indian Desert*' was published in two parts, the Part I of which contained the list of plants including some new species and ecological and meeorological notes were given in part II.

They have listed 507 species, belonging to 69 families and 272 genera out of which 440 are indigenous. Although the nature of Flora is mixed but Western elements are preponderant in the region.

Blatter and Hallberg followed Schimper in describing the types of vegetation and cali it as formations on the basis of edaphic factors. Five main types of formations were recognised by them Aquatic, Sand, Gravel, Rocky and Ruderal. These formations were further divided into smaller units of associations (Warming) and families (Clements).

Though this was an epoch making work in the history of Indian Desert plants and has remained so for a number of years and shall still remain the basic work on the vegetation of this area for some more years to come, it is only a list of plants occuring in different habitats and localities. The absence of descriptions etc. render it unsuitable for identifying plants in a satisfactory manner. And, this, it is all the more regeretted, as Fr. Blatter was, we believe, a systematist of a great promise, quite able to have determined the plants of the regions which he explored. Moreover, the Indian Desert covers much more area than the places they visited. They did not visit the N. E. and the interior of the western desert.

Sabnis (1919-21) who accompanied Blatter and Hallberg studied physiological anatomy of the plants of the Indian Desert. He selected representative plants from different parts of the desert and examined 50 families, 125 genera and 165 species, and the endeavours of his results were published in the *Journal of Indian Botanical Society*.

Agarkar (1920) studied the means of dispersal and the present day distribution of xerophytes and sub-xerophytes of the N. W. India and traced their origin. A note on the ecology of the plants of the Indian Desert (Sind) was published by Sabnis in 1929.

Champion (1936) recognised the following types of vegetation in Rajputana :

5b, C1 Northern Desert thorn forest.

5b, C2 Northern *Acacia* scurb forest in regions with rainfall between 20″-40″.

5b, C3 Northern *Euphorbia* scrub.

D. Tr. E/10 Inland dune scurb.

Calder (1937) an Ex Director of the Botanical Survey of India and Superintendent of the Royal Botanic Gardens, Sibpur, in '*An outline of the vegetation of India*' recognised the desert area under the "Indus plain region" one the of seven regions of vegetation types of India which he distinghuished. According to him the whole area attracts "physiological botanist and ecologist rather than as systematist.

Y. Ramchandra Rao (1941) while studying the habits and ecology of the Desert Locust p blished a list of some of the more common plants of the desert area of Sind, Baluchistan, Kathiawar and S. W. Punjab. The local names of the plants, as they are known in different linguistic areas, have also been given.

Bhadawar, Dey and Griffith, (1948) recommended 250 species suitable for afforesting arid and semi-arid areas, particularly of the Indian Desert. This list includes both indigineous and exotic species.

With the advent of the independence of our country, a new chapter was opened in the study of the vegetation of the Indian Desert. It marked the period of renissance in the history of the study of vegetation of the Indian Desert. It is significant that to begin with almost all the papers came from within the boundary of Rajasthan. The start was made from the Botany Department of Jaswant College, Jodhpur, and some papers on the ecology of the desert vegetation were also contributed by the staff of the Botany Department of Birla College, Pilani.

Shanti Sarup (1951) to start with published a preliminary list of the plants of Jodhpur and its neighbqurhood which was published in the Rajputana University Studies. This has since been revised and printed again (1954 a). Another list of plants of N. W. Rajputana was published by Sankhla (1951) in the same journal which ennumerated nearly 500 species of flowering plants with their life forms. The ecological studies of the vegetation of the Indian Desert was renovated by the publication of the "*Biological spectrum of the Flora of the Indian Desert*" by Dass and Shanti Sarup (1951 . A comparison was made with the climates of the other deserts and the vegetation was characterized as *Chaemophytes and Therophytes.*

Mulay and Ratnam (1950) contributed a paper on the ecology of the vegetation of N. E. Desert areas (Pilani) and classified the vegetation as *Capparis-Prosopis* formations. Ramchandaran (1950) studied the grasses of area round about Pilani and pointed out that there are typical *Psamophilous* grasses growing in the area. Only the abstracts of this appeared in the *Proceedings of the Indian Science Congress.*

Ratnam (1951) surveyed the vegetation in the hilly tracts of Eastern Rajputana (Lohargal) and arrived at the conclusion that the factors governing the growth and developement of vegetation are different in the two regions and consequently the vegetation of the hills differ from that of the plains of Rajasthan.

Shantisarup (1952 c), contributed a paper to the 39th Indian Science Congress on '*The Vegetation of Jodhpur and its neighbourhood*', which mainly deals with different ecological formations.

Then came the most important event in the progress of study of the vegetations of the Indian Desert, which renewed the interest and enthusiasm of those interested in the study of Indian Desert vegetation—a symposium on the *Rajputana Desert.* The Government of the country (and of various provinces) and its scientists realised that the conditions of Rajputana Desert are deteriorating. Fear was expressed that the desert is spreading at an alarming rate; the Government of the provinces planned to arrest the spread of Desert and reclaim a part of it. Above all the council of *National Institute of Sciences of India* decided to arrange a Scientific discussion of all aspects of India Desert Sciences-Geology Chimatology, Soils, Water, Archeology, Biology etc. A steering committee was appointed by the council to arrange a symposium on 7th and 8th March, 1952 in the Institute's new Building at New Delhi.

A generous response was a matter of deep satisfaction and the preceedings of the symposium were published in its Bull. No. 1, Nat. Inst. Sci. India, September, 1952.

It is out of scope for an article like the present to review all the papers presented to thiss ymposium but we shall give short reviews of only those papers which are directly concerned with the study of the vegetation of the Rajputana Desert.

Though the papers dealing with the vegetation of the area, are only a few, they are so varied that their importance becomes evident in the study of the vegetation of the area. Shantisarup (1952 a) in an extensive paper dealt with the extent and development of the desert and the influence of climatic, edaphic and biotic factors in the "Distribution of the vegetation of the area".

Three ecological zones are recognised :—

1. To the south and south east of the Region near the Arawalli hills but not strictly in the desert. Here some natural vegetation is found.
2. Semi-arid region about 100 miles parallel to the first region where plants of the most xerophytic type are fonnd.
3. The arid region to the extreme north and west of the region. Here the vegetation is very poor.

Dr. G, S. Puri, (1952) in an excellent paper reviewed the position of plant Ecology of the deserts of Rajasthan and Saurashtra. He suggested some important and essential measur e to be adopted in attempts to afforest the area.

Prof. S. P. Agarkar, Director, Maharashtra Association, for the cultivation of Science, contributed a paper on the plant Ecology of the Rajputana Desert. Dr. K. Biswas, Superintendent, Indian Botanic Gardens, Howrah, in a short paper on the "*Desert vegetation*" regards only a few places as true desert. He after discussing the general aspects and problems of the Indian Desert concludes by pointing out the vast opportunities for studying the various problems associated with the plant life in the desert areas. Dr. Hora, (1952) president, Nat. Inst. Sci. of India, while reviewing these papers presented at the spmposium observed that the Flora of the region is not so poor and that with suitable experimentation, it may be possible to find indigenous species, which may thrive well in the arid and semi-arid regions to form a protective vegetable cover.

Another symposium was held at Jerusalem by the Research Council of Israel, in co-operation with the specialised agency of U. N. E. S. C. O. on Arid Zone, in May 1952. Shantisarup (1952 b) contributed a paper to this symposium on the Ecology of N. W. Rajasthan.

A series of contributioas to the plant ecology then followed from the Botany Department of Jaswant College, Jodhpur. Shantisarup and L. N. Vyas (1953 & 1954) undertook an ecological survey of representative areas and habitats taking into considera-tion the edaphic, climatic and biotic factors. Various plant communities were studied and their relationship pointed out. The animals exercise a very adverse effect on the vegetation, destroy-ing it ruthlessly. Shantisarup and Kishan Dutt (1954) studied the vegetation of Jodhpur in relation to the soil and analysed the various edaphic factors and their role in determining the nature of vegetation.

Puri and Shantisarup (1954) have recently contributed a paper on the Vegetation Types of the Rajasthan Desert.

The reaction of the individual species to its habitat and environment play an important part and more so, in the dry and barren areas, where the vegetation is sparce. With this peint in view, Shantisarup and S. P. Singh (1953) studied the autecology of *Tephrosia purpurea* Pers.—a very common perrenial plant of the Indian Desert found in all odd habitats. It has been concluded to utilize this species in formulating schemes for afforestation. *Gynandropsis pentaphylla* DC. was another such plant, the autecology of which was studied by Shantisarup and Tandon (1954). Autecology of *Anisochilus ericephalus* Benth., *Mullogo nudicaulis* Lamk. and *Mullugo cerviana* Serr. have also been studied by Bakhsi (1952) and Bakshi and Kapil (1953, and (1954) respectively.

Biswas and Rao (1953) dealt with the Rajputana Desert against the background of the deserts of the world and divided it into three Zones: Desert 5″-10″, Arid 10″-20″, Semi arid 20″-30″, on the bais of edaphic factors. The vegetation has been divided into sand community, gravel community, the rock community and ephemeral community. A list enumerating the plants of the region which are available in the literature and also in the Calcutta Herbarium has heen added.

Shantisarup (1954b) observed that undulations play an important part in the water economy and hence the plant life of the semi-arid regions of the Indian Desert. A very general feature of the plains and hills, here is the formation of depressions of various dimensions. Subsoil moisture of these depressions is always more than that of the neighbouring tracts. This helps more plants to grow. Artificial buuds etc. could help utilize this feature for afforestation of the region with *Prosopis juliflora* and other species.

Recently Bakshi (1954, has published a detailed account of the plants of Pilani and its adjacent areas.

The systematic study of plants and their ecology is very important to understand the structure and the composition of the vegetation, but the physiology, physio-ecology and anatomy of these plants equally play an important role in formulating important schemes of afforestation and reclamation of the desert. A start in this direction was made by Dr. Sabnis (1919—21) who accompanied Blatter and Halfberg and worked out the physiological anatomy of characterstic desert plants of India.

This is probably ths only record of study of the physiological anatomy of the Desert plants. Ratnam renovated it. Tuberization of roots is an important phenomenon, commonly met—with in the plants of the arid and semi—arid areas. Ratnam and Kapoor (1953) corelated the morpbological features in the tubersization of roots of some common Indian Desert plants with that of environmental factors. Ratnam and Bhargava (1954) studied the effect of photoperiod, and Ca, K and Mg on the physiology of some local plants. The study of transpiration of desert plants being an important phenomenon Ratnam and Daulal (1953) studied the transpiration of some common Indian Desert plants. The distribution, morphology and anatomy of nine species of local plants have been corelated with the rate of their transpiration. These results reveal that in the afforestation schemes common local plants like

Crotataria burhia, Birleria acanthoides, Leptadenia spartium, Aerua pseudotomentosa etc. are of great significance. Ratnam and Prithvi Singh (1954) studied the absorption of water by roots and their relation to the stomatal apertures in some of the Indian Desert plants. The physioecological status of these plants have been studied and it has been concluded that these plants require scanty water and can very well act as sand binders.

The vegetation of the Indian Desert has been divided by almost all the workers, on the basis of edaphic factors into five formations—Sand, Gravel, Rocky, Aquatic and Ruderal. In order to review the vegetation types of the Indian Desert plants, short review of these various types is necessary.

DUNE VEGETATION

The sand dunes of the Indian Desert constitute a well defined ecological and vegetational entity. Blanford (1876) who visited some parts of the Indian Desert studied its physical geography with special reference to the formation of sand hills. According to him three types—the longitudinal dunes, the Barchans and the transveroe dunes,—occur in the Indian Desert. According to Oldbhm (1893, all these are due to the characterstic action of wind, but longitudinal dunos occur where wind is stronger. Raychaudhuri and Sen (1952) are however of the opinion that where the wind is stronger dunes of transverse type occur. La Touche (1902) observed that big trees occur on the leeward side of the transverse dunes: indicative of stabilization for considerable time. Raychaudhuri and Sen (1952) on this basis conclude that the dunes are generally established in the North-east due to the encroachment of the vegetation. According to Blatter and Haliberg (Loc. cit.) some times these dunes are formed with extreme rapidity in few hours, but when they are in hollows between two hills they are stationary. Formation of wind ripples is another important feature of the wind on sand, the later due to constant forward motion make the germination of seeds more or less impossible according to these authors. They studied the characterstic associations and conassociations of the dune plants and pointed out that *Calligonum polygonoides, Aerua tomentosa and A. pseudotomentosa, Indigofera argentea. Leptdenia spartium. Crotalaria burhia Citiullus colocynthis, Farsetia sps., Calotropise procera* and many grasses particularly species of *Panicum*, *Eleusine*, *Cenchrus catharticus* and stoloniferous *Cyperaceae* play an important part in the fixation of these dunes and in the process of sand binding.

GRAVEL VEGETATION

The gravel is a coarser type of sand and the vegetation peculiar to it is known as the Gravel formation. It covers a very large area of the Indian Desert; this is because Indian Desert is not a true desert. The wind picks up and transports the grains of the gravely soil, depositing them finally on dunes, but cannot move larger particles to any large extent (Blatter and Hallberg). Although the colonization of the region becomes evident in as much as the gravel vegetation is effected to a lesser extent by the prevailing winds and the seed germination is generally easier in this habit and once the vegetation is established, it checks to a considerable extent the loss due ta soil erosion and runoff. The typical gravel plants are *Fagonia cretica*, *Boerhaavia diffusa*, *Cleome papillosa*, *Eliusine sp* , *Aristida sp* , *Tribulus terrestris*, *Corchorus* and *Indigofera sps*. Most trees and shrubs of the region belong to gravel formation, e, g. *Gymnosperia montana*, *Capparis*, aphylla, Zizyphus sps, *Prosopis spicigera*, *Acacia arabica*, *Acacia senegal*, *Salvadora oleoidis and S. persica* etc. An interesting ecological change has been recorded by Blatter and Hallbarg of *Calligonum polygonoides* a typical dune plants 'which coriously enough in such habitats' has been reported to become a large climber. Bhandari (1954) is however, of the opinion that the plant *Ephedra foliata* Boiss, a climber, has been mistaken as *Calligonum polygonoides*. The typical gravel plants may either have stify, more or less woody branches and lie flat on the ground or have bushy habits. Impor tant associations of gravel plants have been studied by all the above mantioned authors.

ROCKY VEGETATION

The main rocks of Aravallies are Acchaean gacisses, micaceous and hornblends schists, marble and quartzites. The soils here are shallow and unstable bearing a dry type of forest, (Puri 1952). Blatter et al. (loc. cit.) visited only three rocky areas (i) Kailana and Mandore near Jodhpur, (ii) Jaisalmer and (iii) Barmer. These three areas show distinct differences as regards the floristic composition of their association. Though most of the species occur in only one or two areas and many are common to all the three yet showing striking variations in their frequency. The commonest plants of such formations are: *Euphorbia neriifolia, Grewia populifolia, Barleria acanthoides, Asparagus racemosus, Barleria prionitia, Farsetia macrantha* a few *Malvaceae, Lepidagathis trinervis, Tephrosia purpurea, Oryzia decumbens, Salsola foetida* and many grasses. The xerophytic fern *Actinopieris dichotoma* is also common in crevices and shady places higher up on these hills and the evidence of cryptogamic life is also not uncommon after heavy rains particularly 2-3 sps. of *Riccia*, a moss, many Lichens and some Blue green Algae.

AQUATIC AND SEMI AQUATIC VEGETATIUN

Water is very scarce in the Desert areas and therefore where ever possible artificial water reservoirs have been constructed preferably with rocky basins. Blatter and Hallberg (loc. cit.) have enumerated some aquatic and semi aquatic species occuring in these reservoirs, ponds, pools and puddles. According to them the submerged flora is rather poor and very local. On the other hand the semi—aquatic flora is well developed. The absence of *Hydrocharitaceat, Rotala* and aquatic grasses is conspiuous but the occurrence of two species of *Natas, N australis* and *N, welwitschii* both of which are new to India is very interesting.

Biswas and Rao (1953) listed 27 species of aquatic and semi-aquatic plants in the desert lakes and ponds, which have been reported in the previous literature. In these papers there is a mention of only one species of *Chara* forming aquatic algal vegetation. Bhandari (1952) in a preliminary report on the algal flora of the water reservoirs, other semi-aquatic and subaerial habitats, has reported 109 species of algae occuring in Jodhpur and its environs and out of these there are 6 sp. of *Chara.* Shantisarup (1954) has studied the aquatic and semiaquatic vegetation from the water reservoirs of Rajasthan and has reported 57 species belonging to 17 families and 40 genera besides species of *Chara* and *Marsilea*. Some aquatic associations found in the area are mentioned. The distributitn of the water plants of Jodhpur throw some light on the origin of the flora of the desert area.

SALT PROBLEM AND HALOPHYTES

Salts of various types occure in the soils, surface and underground water of Rajasthan Desert, Major Hacket (1881) was the first to examine it in details. Holland and Christie (1901) proposed a wind brone theory for the origin of salt in Rajputana Desert. This theory has come under severe criticism by Godbole (1951). Auden (1949-1952) raises some difficulties in supposing that the present salt lakes have any connection with Mesozoic and Eocene seas. He has listed number of points which are not understandable on Godbole's hypothesis. Various arguments have been given for and against these theories.

This salt problem has been little studied in relation to vegetation. Aquatic vegetation particularly the algae has been studied from time to time and important conclusions derived regarding the origin of salinity of Rajasthan from these studies.

Blatter and Hallberg (loc. cit) have mentioned a few halophytic species. Recently Biswas and Rao (loc. cit) have listed halophytic species of Rajputana Desert. Shantisarup and Kishan Dutt (1954) studied the halophyte of Luni river bed in relation to soil structure and composition and a detailed analysis of the soil-plant-communities have been recorded. Shantisarup and Vyas studied the salt plants occuring in Jodhpur Tehsil. According to Shantisarup (1954) *Tamarix dioica, and Tamarix gillica*, gregarious trees are common on the banks of the saline depressions. The other common plants are : *Halaxylon salicornicum. Bge. Salsola foetida Del, Suaeda. fruticosa* Forsk. *Atriplex crassifolia* Ctulay. *Plucheal anceolata. etc.* These areas represent another ecological unit with scanty yet distinctive type of vegetation. He has now under taken a systematic study of the halophytes of Pachpadra, and other saline areas of the desert.

The salinty of Rajputana desert is widespr ad and extensive. The causes of its origin still remain to be explained. They are responsible for the formation and expansion of the desert.

SOILS AND VEGETATION

The systematic study of the soils of Rajasthan Desert is scanty Wadia, Krishnan and Mukerjee (1935) designate the Desert soils to be mainly composed of wind blown and locally disintegrated sandy soils of alkaline and salty nature. In a map accompaning their paper, they record saline sand, slit and muds, saline and alkaline soils and blown sand in the desert. In the first soil map prepared in 1943 much of the soils of Indian Desert have been classed as coarse alluvium. Raychaudhuri and Mukerjee (1947, in a recent map have named them as Desert Soils. The desert sands of Marwar were examined by Proof, G. R. McCarthy (1935) of North Corolina, who compared these soils with the soils of the desert regions of different parts of U. S. A. and Algeria. According to his finding they are of eolian type-a type which could have easily rolled along the ground rather than blown through the agency of wind. These sands contain variable quantity of lime.

According to Raisinghani and Pithawalla (1943, the alluvial soils of valleys are definitely richer than that of the hill surface and the silt content of the former is also greater. Pithawalla (1937, '42, '41, '52) observed that these desert sands have been derived from (a) Subaerial denudation of rocks (b) Aeolian sources (c) Ancient coasts of estuaries, (also mentioned by Oldham, 1893).

Mostly they have been derived from rocks and transported by mighty rivers in the past ages, (Pithawalla 1935). Ghosh (1952) advocated the study of Desert sands since it has an important bearing on the question of its movement and prevelance. Raychaudhari and Sen(1952)studied the burried soils of Rajputana. Thamne (1952) contributed a paper on the soils of Rajputana and Sind deserts to the Rajputana Desert Symposium. He divided the soils of Rajputana in two regions; those to the Northwest of Aravalies are wholly sandy, illwatered and unproductive but are more fertile in the Easternsides-where they change from sandy to clayey in character. The second region lying S.E. of Aravalies is fertile. Kantikar (1952) observes that the soils of Western Rajputana in particular are deficient in organic matter, nitrogen and phosphoric acid but all these deficiencies oan be made good by proper methods of cultivation, rotation and manuring. Ray. chaudhari (1952, in another article '*Desert soils and Desert farming*' classified 1/8 of the total cultivatable land occupied by Desert soils as light loams and heavy loams. There is a great depth of loose sediment and the amount of clay is less in surface but may reach about 40% in the lower layers. This is probably due to erosion and runoff. On the basis of the ffnal report of all India soils survey schemes (1948 he has grouped the Bikaner soils under grey soils which develop salinity and alkalinity due to low rainfall and high evaporation.

These soils have poor water holding capacity a fact which has a profound effect upon the vegetation and the development of the plants. Little work if any has so far been done as regards the nature of soils in relation to its vegetation. Blatter and Hallberg (loct: cit.) on the basis of edaphic factors classified the vegetation of the desert under various formations Soils types is one of the important factors influencing and determining the vegetation of the desert area (Shantisarup 1952). The subsoil water supply is very poor because in the major part of the desert it is derived from the precipitation which is low. The only source is the subsoil water. The subsoil water of basins being high they show better growth and frequency of vegetation. The presence of salt in the soil is another important factor which determines its vegetation. Puri (1952) also divided the vegetation on the basis of the nature of soils as has been done by Blatter and Hallberg. Ratnam and Kapoor (1953) studied the physical and chemical aspects of local soils in Jodhpur and corelated them with the morphological features and tuberisation of the roots of some of the Indian Desert plants. Shantisarup and Singh (1953, & Shantisarup and Tandon (1954) studied the soils of different regions round about Jodhpur in connection with their studies on the autecology of two local plants. Shantisarup and Dutt (1954) studied the soils in relation to the vegetation of some parts af the India Desert.

CLIMATES

Climate of an area plays an important part in the formation and maintenance of arid and semi-arid conditions. Metrological data particularly with reference to rainfall and temperature of the area have been recorded since the last quarter of the last century. (Adams, 1899; Imperial Gazzeter 1907; Blanford 1899). Blatter and Hallberg also gave certain meterological data of the parts of Jodhpur and Jaisalmer. But it is in the recent years that the climates of Rajasthan have been studied in details; though much remains to be done even now. Banerji 1952) studied the weather factors in the creation and maintenance of the Rajputana Desert-a desert which occupies a worst position in the Hot Deserts of the world. He studied the climatic variations, rainfull and its distribution in space, aridity factor with precipitation ratio; isolation, thermals, solar energy and the probable factors affecting the rainfall. Pramanik and Hariharan (1952) studied the main climatic features of Rajasthan by examining the meterological data of the observatory stations is Rajasthan. Rainfall, temperature, humidity, wind, thunder storms, dust storms, hail and fog etc. of the area have been studied and noteworthy features have been brought out. In another paper Pramanik, Hariharan and Ghose (1952) studied the meterological conditions in the extension of the Rajasthan Desert. In a separate paper Ramanathan (1952) studied the atmospheric conditions over the Rajputana Desert. Pramanik (1952) studied the *Hydrology oj Rajasthan Desert* including Rainfall humidity and evaporation, the last of which being many times the rainfall, has also been estimated, Evaporation has been studied at different places in the region by Fergusson (1944), Raman and Satakopan (1948) etc. Ramdas (1952) in an article on Desert. Hydrology studied the condensation and evaporation phenomenon in the Rajasthan Desert. The hydrology of the Rajasthan has also been studied by Dhir and Krishnamurty (1952). According to Stampe (1940) the region is cut off from the north by crustal upwarps. Subsoil water is therefore not received from the plains of the adjacent areas. Taylor (1952) studied the occurence of ground water in rocks of western Rajputana.

ARECHEOLOGY

The arecheology of the Rajasthan Desert has always had an important bearing on the geology and geography of the Indian Desert. Important contribution have been made to this aspect, by many arecheologists—Blanford (1876-77,; Oldham (1874-1893,; Setin (1942: Vats (1952 : Krishnamurthy (1952); Mitra (1952,; Sankhlia (1952) etc.

Afforestation and immobilization of the Indian Desert

The recent survey of the India Desert shows soil erosion in the area is wide spread. It has been realised that afforesta of these tracts is an important problem demanding immediate ettention. Bhadwar, Dey and Griffith (1948) have advocated the introduction of some indigenous and exotic species for this purpose. Recently, however, the problem has been stressed more than once. Banerjee (1952); Chaturvedi (1952); Gambhir Singh (1952 a & b); Puri (1952 ; Ganguli 1952): Khosla (1952); and Shantisarup (1954).

PRACTICAL STEPS TOWARDS IMMOBILIZATION OF THE DESERT

The Ministry of Food and Agriculture established a Desert Afforestation Research Station, under the *aegis* of F. R. I. Dehradun at Jodhpur to study, *inter alia*:—

1. The silviculture of indigenous species with particular reference to their succession in the saline drifts, sandy soils and mountanous tracts; the influence of biotic factors on their development and methods of propogation and establishment.

2. The possibilities of introducing exotic desert species from other countries and from other parts of India, such as indigenous *Kochia indica*, *Prosopis juliflora*, (an *Arizona*, U. S. A. *emmigrant*) *Agave americana; Acacia gregei* (from America) *Mesembryanthemum edule* (from Newzealand), Russian olive from Afghanistan and others.

3. The edaphic factors especially the problem of salt in the soil.

4. Hydrological conditions, rainfall and wind velocities and the nature of aeolian deposits.

I. The station maintains a large store for distribution, free of cost, of seeds of various desert species that are comparatively immune from browsing.

II. The station has also organied—

(a) The creation of oases of vegetation around various public institutions and stations.

(b) Creation of a belt approximately 400 miles long and 5 miles wide, parallel to the Pakistan boundry and located about 5 miles, inwards the western boarder of Rajasthan. Jodhpur, Jaisalmer strip is the first phase of 400 miles long, five mile wide shelter belt that will ultimately fringe the entire Bakhasar-Gangapur arch, streching from the Runn of Cutch to PEPSU.

(c) Establishing shelter belts along selected roads (Pali-road. Jaipur-Alwar, Churu and at other roads) and railway lines, (Jodhpur-Pali, 15 miles north of Bikaner, Jaipur, Sikar, Fatehpur and other places) running transversely to the direction of winds.

(d) A nursey at Jodhpur and eight other centres-Gadra Road, Barmer, Pokaran, Pali, Beriganga, Jhunjhunu, Sardarsahar, and Chirawa and an arboretum at Beriganga.

(e) Afforestation of some blocks of not less than a thousand acres each on different types of soil and rocky area-Jhunjhunu, Kailana, Pali, a semi-arid piece at Shekawati and a shifting sand site at the Rural University at Sardarsahar.

(f) Wide publicity indicating.

(i) Harmful effects of cultivation on dunes.

(ii) Advantage of creating wind-breaks around each field.

(iii) Correct Agricultural practices.

(iv) Improved methods of lopping.

The state forest department is increasing its forest area and other agencies and Government departments are helping in the work in all allied spheres.

The UNESCO has sanctioned, under its Arid Zone Research programme (1) a scheme by Professor Shantisarup for the study of the Flora of the Rajasthan Desert and the preparation of a herbarium thereof (2) a scheme by Dr. F. R. Barucha for a Phyto-siological study of the vegetation of the Rajasthan Desert,

Some positively good work on these lines is being done.

A project financed by UNESCO is already under headway under the supervision of Dr. Daya Krishana, Professor of Zoology Jaswant College, Jodhpur to study the role of Vertebrate Animals in the creation and maintenance of the desert conditions.

SOME PROBLEMS IN THE IMMOBILISATION OF INDIAN DESERT

The main problem the selection of species to be used for the control of the loose sand is two fold—(1) the selection of species for perennial cover and the selection of species for cover during the rainfall of the local perennial species, *Prosopis spicigera Linn. and Calligonum polygonoides* Linn. might be used to some extent. *Prosopis glandulosa* which is less woody and grows more rapidly, however is more suited than the native species. It coppices well and regenerates naturally. Its water requirements are also not so great as that of the other species tried in others deserts:of the world. It is also suitable for covering the rocky areas and some parts have been successfully afforested with it. *Calligonum polygonoides* Linn. is also a useful plant for being introduced in the interior of the desert as a dune cover.

During the rains the commonest plant is *Tephrosia purpupea* Pers. It covers the soil. The root and dry branches remain in the soil even after the rains and may continue as such till late in the season. It is probably a recent introduction and is spreading quickly, Its cultivation along with those of other species should be extended into the interior of the desert. It is also useful for covering the sand dunes. At such places *Saccharum spontaneum* Linn. has proved very useful.

These species are to some extent able to control water erosion.

Some of the other lines of work in this direction with problems of their own, are :—

1. The improvement of grazing lands by rotation, enclosure and the introduction of legumes.
2. There is constant breeze in the desert for major part of the year which could be used :
   - (a) for wind mills for drawing water and as a source of engergy for other purposes.
   - (b) As an aid for artificial rain making during the period it is charged with water and which is to be countracted
     - (i) by road side planting and
     - (ii) planting along railway tracts.

(c) Wind breaks, shelter belts, etc. to minimise wind erosion and dessication and march of the desert.

3. The problem of salt in the soil and its removal by planting.

4. The control of destruction of vegetation and deterioration of the area.

5. Co-ordination of studies and afforestation work done by the various agencies and the public sector and formation of an Over-all-organization. Some of these problems in the immobilization of the Indian Desert have been outline by Shantisarup (1954).

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