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CHEMICAL INTERACTIONS BETWEEN SEEDS OF COMMON SPECIES

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Chemical interactions between germinating seeds of 58 common species were studied *in vitro*. Five distinct types of chemical interactions were recognized, i.e. one-way inhibition, mutual inhibition, one-way stimulation, mutual stimulation and both-way interaction. The predominant type of interaction was one-way inhibition.

Fifty-one species were found to be chemically reactive to some extent but only 9 species were highly reactive. All the reactive species can be classified into 6 groups, viz, exclusively inhibitory (16 species), mostly inhibitory (9 species), exclusively stimulatory (5 species), mostly stimulatory (4 species), mixed type (16 species) and mostly interacting both-way (1 species). Among the inhibitory species weeds and halophytes formed the majority.

The number of species found to be reactive was highest in plants of waste lands and alluvial plains.

The predominant interaction in plants of alluvial plains, saline soils and inland sand dunes was mostly inhibitory. The plants of waste lands, dry stream banks and calcarious hills contained an equal number of inhibitory and stimulatory species. Lowlands flooded seasonally had mostly species producing mixed type of interaction.

The inhibitory interactions shown by a large number of species appears to have adaptive correlation with arid environment mainly by reducing competition between plants.

Interactions of a chemical nature between higher plants have been studied. Such interactions are ecologically very effective not only in natural plant communities but also in crop and weed populations However, very little work has been done on chemical interactions between different seeds during germination. Evenari[1] reviewing the literature on such phenomena cited several interactions between seeds of certain crops and weeds which appeared to be very important from the agricultural point of view.

In Pakistan no work has been done in this particular field. The present paper is an attempt to elucidate the complex and hitherto unreported interrelationships between native plants during germination. Work on soil conditions affecting interactions between seeds is in progress and will be reported elsewhere. Isolation and identification of the chemicals involved is also being contemplated.

Review of Literature

The number of publications dealing with the chemical interactions between seeds of different species are rather scanty. Evenari[1] in his review of the work by Froschel and Funke, Rademacher and Ullman, refers to the phytosociological importance of chemical interactions between seeds. These workers found out that certain seeds inhibit germination of other seeds when sown together in pots containing soil. For example, wheat grains do not germinate when planted with *Viola* seeds. Wheat and rye grains suppressed the germination of such weeds as *Anthemis arvensis*, *Matricaria inodora*, etc. *Melandrium* sp. and rye did not develop if *Beta* seeds were present. Most seeds, containing essential oils, alkaloids and glucosides, inhibit germination and development of seeds of other species which may be present in their vicinity.

Evenari observed that the germination inhibiting substances occur in all parts of plants, i.e. fruit pulp, fruit coat, endosperm, seed coat, embryo, leaves, bulbs and roots. As already recognised the main inhibitors comprise such compounds as hydrogen cyanide, ammonia, ethylene, mustard oils, organic acids, unsaturated lactones, aldehydes, essential oils and alkaloids.

The seeds of certain desert plants contain one or more inhibitors which keep the seeds dormant during unfavourable seasons.[2,3] Such seeds require specific amount of rainfall so that the inhibitors may be washed away thoroughly before germination may result. Evidence of the presence of inhibitors in seeds and fruits of some desert plants has also been brought out by Mayer and Poljakoff-Mayber.[4]

A number of organic substances are known to be released from seeds and fruits of several plants. Borner[5] has reviewed the literature recently. His review of earlier work of Moewus *et al.* Niemann, Knapp and Toole *et al.* is particularly pertinent here. According to him five groups of chemicals, i.e. amino acids, sugars, flavones, phenolic compounds and gases are released from seeds and fruits. A brief account of these groups is as follows:

Amino Acids and Sugars.—The seeds and/or fruits of *Trifolium repens*, *Lolium perenne*, *Artemisia ab-*

sinthium, *Secale cereale*, *Hordeum vulgare* and *Triticum aestivum* liberate alanine, aspartic acid and glutamic acid. The first two species also release serine, while the last three species exude valine, leucine, asparagine, glucose and fructose.

Flavones.—The seeds of *Trifolium repens* and *Trifolium hybridum* excrete a yellow dye within 24 hr after being placed on moist filter paper. Quercetin and myricetin from *Trifolium repens* and myricetin from *T. hybridum* have been identified.

Phenolic Compounds.—The seeds of flax when kept on moist filter paper for 12 hr release a glycoside which forms aglucon and glucose. Besides aglucon, ferulic acid, *p*-coumaric acid and *p*-hydroxybenzoic acid were also identified in the filter paper.

Gases.—Ethylene, ammonia and hydrocyanic acid have been reported. Ammonia released from the seeds of *Beta vulgaris* completely inhibited the germination of *Agrostemma githago* seeds when kept moist in petri dishes.

Borner[5] also referred to the work of Ullman and Grümmer who showed that bitter almonds containing amygdalin inhibit the germination of wheat and poppy seeds when moistened together in petri dishes. These investigators assumed that amygdalin is broken down by enzyme action into glucose, benzaldehyde and hydrocyanic acid.

Bernhard[6] studied the inhibitory effect of radish seeds and found that the inhibitory substances were coumarin along with eight coumarin analogues; the former was more effective.

Among the inhibitors identified in fleshy fruits, Mayer and Poljakoff-Mayber[4] reported *p*-sorbic acid in *Sorbus aucuparia*, ferulic acid in tomatoes, a mixture of organic acids in lemon and strawberry. In dry fruits, the only inhibitor identified is coumarin in fruits of *Trigonella arabica.* In *Fraxinus excelsior* the presence of an inhibitor in the embryo itself has been shown. These substances inhibit their own seeds. However, Cornman[7] reported that certain plants did not grow until *p*-sorbic acid in the fruits of *Sorbus aucuparia* was destroyed or leached out.

Occurrence of inhibitors in the seeds of local species has been indicated by Lodhi and Qadir,[8] Lateef and Qadir[9] and Habibunisa and Qadir.[10]

Materials and Methods

Weekly field trips were made in an area about 60 miles around Karachi during 1966–1967. The seeds of 58 species were collected from diverse habitats and kept in paper bags.

For the study of interactions between seeds, 385 combinations were made. In each combination, 20 seeds of each of two species were thoroughly mixed together and were placed on a moistened filter paper on the bottom of a 6 in dia petri dish. The filter papers were daily moistened throughout the experiment. Similarly, the seeds of the two species were put up for germination in two petri dishes separately. This served as control. Observations of germination were made daily up to 25 days. The percentages of germination in control as well as in the combinations were calculated after the end of the experiment.

The seed combinations were made in such a way that as far as possible the seeds of species occurring in similar habitat conditions were combined together two at a time.

Results

Tables 1–5 indicate that most probably certain seeds release chemical substances which affect the germination of other seeds in their vicinity. The data point out the possibility that the chemical interactions between the seeds of species at germination level may be quite widespread and may be very important ecologically.

In all 385 combinations were tried, out of which 100 combinations were positive in the sense that they indicated chemical interactions of various types. The total number of species used in these combinations was 58 of which 51 species showed positive reactions and constituted 86.32% of the total species tried. Only 7 species showed negative response.

Among the 51 positive species, a number of highly reactive species are recognizable (Table 6). The highly reactive species were those which affected the germination of large number of species. These species were *Suaeda nudiflora*, *Atriplex stocksii*, *Pteropyrum oliveri*, *Suaeda monoica*, *Aristolochia bracteata*, *Convolvulus glomeratus*, *Salvadora oleoides*, *Lycium europeum* and *Cassia holosericea*.

Classification of Types of Chemical Interactions

Five distinct types of chemical interactions were found which are as follows:

One-way Inhibition.—Chemicals released from certain seeds inhibited the germination of another species, 44 combinations showed this type of interaction (Table 1).

TABLE 1.—LIST OF SEED COMBINATIONS SHOWING "ONE-WAY INHIBITION".

No.	Name of species	Germination at control %	Germination in combinations %
1	*Acacia senegal* Willd	70	10
	Salvadora oleoides Decne	0	0
2	*Capparis decidua* Forsk	60	0
	Indigofera oblongifolia Forsk	0	0
3.	*Capparis decidua* Forsk	60	0
	Salvadora persica L.	70	70
4.	*Acacia senegal* Willd	70	20
	Grewia tenax (Forsk.) A. & S.	0	0

(Continued)

(Table 1 continued)

5.	*Citrullus colocynthis* (L) Schrad.	90	40
	Gynandropsis gynandra (L.) Briq.	0	0
6.	*Citrullus colocynthis* (L.) Schrad.	90	40
	Suaeda nudiflora (Willd.) Moq.	10	10
7.	*Capparis decidua* Forsk.	60	10
	Convolvulus glomeratus Choisy.	0	0
8.	*Heliotropium europeum* L.	50	0
	Cassia holosericea Fres.	0	0
9.	*Acacia senegal* Willd.	70	30
	Commiphora mukul (HK.f. ex stocks) Engler.	0	0
10.	*Capparis decidua* Forsk.	60	20
	Gossypium stocksii Mast.	0	0
11.	*Solanum incanum* L.	40	0
	Corchorus depressus (L.) Stocks.	0	0
12.	*Breweria latifolia* (Hoechst. & Steud.) Benth.	0	0
	Barleria acanthoides Vahl.	40	0
13.	*Solanum incanum* L.	40	0
	Cassia holosericea Fres.	0	0
14.	*Atriplex stocksii* (Wt.) Boiss.	40	10
	Schweinfurthia papilionacea (Brum. F.) Boiss.	0	0
15.	*Cressa cretica* L.	40	10
	Salvadora oleoides Decne.	0	0
16.	*Heliotropium europeum* L.	50	20
	Heliotropium subulatum (Hoechst.) Vatke.	0	0
17.	*Indigofera cordifolia* Heyne.	30	0
	Heliotropium subulatum (Hoechst.) Vatke.	0	0
18.	*Indigofera cordifollia* Heyne.	30	0
	Corchorus depressus (L.) Stocks.	0	0
19.	*Indigofera cordifolia* Heyne.	30	0
	Tephrosia strigosa (Dalz.) Sant. & Mah.	0	0
20.	*Indigofera cordifolia* Heyne.	30	0
	Convolvulus glomeratus Choisy.	0	0
21.	*Indigofera cordifolia* Heyne.	30	0
	Leucas urticaefolia (Vahl.) Rr. B.	0	0
22.	*Indigofera cordifolia* Heyne.	30	0
	Cleome viscosa L.	0	0
23.	*Breweria latifolia* (Hoechst. & Steud.) Benth.	0	0
	Cressa cretica L.	40	10
24.	*Aristolocohia bracteata* Retz.	0	0
	Pteropyrum oliveri J. & S.	20	0
25.	*Cressa cretica* L.	40	20
	Salvadora persica L.	70	70
26.	*Cressa cretica* L.	40	20
	Suaeda nudiflora (Willd.) Moq.	10	10
27.	*Suaeda nudiflora* (Willd.) Moq.	10	10
	Suaeda monoica Forks. ex. Gmel.	30	10
28.	*Aristolochia bracteata* Retz.	0	0
	Mimosa hamata Willd.	10	0
29.	*Atriplex stocksii* (Wt.) Boiss.	40	30
	Suaeda nudiflora (Willd.) Moq.	10	10
30.	*Blepharis sindica* T. And.	100	90
	Solanum xanthocarpun Schrad.	0	0
31.	*Citrullus colocynthis* (L.) Schrad.	90	90
	Haloxylon recurvum (Moq.) Bunge.	30	20
32.	*Cocculus pendulus* (Forsk.) Diels.	0	0
	Capparis aphylla Roth.	60	50
33.	*Datura alba* Ness.	10	0
	Cassia holosericea Fres.	0	0
34.	*Datura alba* Ness.	10	0
	Abutilon fruticosum Guill.	0	0
35.	*Lycium europeum* L.	10	0
	Periploca aphylla Decene.	0	0
36.	*Lycium europeum* L.	10	0
	Calotropis procera (Willd.) R. Br.	0	0
37.	*Lycium europeum* L.	10	0
	Convolvulus glomeratus Choisy.	0	0
38.	*Lycium europeum* L.	10	0
	Schweinfurthia pedicellata (T. And.) Bth.	0	0
39.	*Mimosa hamata* Willd.	10	0
	Acacia nilotica (Lamk.) Willd.	0	0
40.	*Peganum harmala* L.	0	0
	Cassia italica Mill. Lamk. ex F.W. Andr.	10	0
41.	*Peganum harmala* L.	0	0
	Mimosa hamata Willd.	10	0
42.	*Trianthema pentandra* L.	10	0
	Corchorus trilocularis L.	0	0
43.	*Trienthema pentandra* L.	10	0
	Corchorus depressus (L.) Stocks.	0	0
44.	*Trianthema pentandra* L.	10	0
	Euphorbia granulata Forsk.	0	0

TABLE 2.—LIST OF SEED COMBINATIONS SHOWING "ONE-WAY STIMULATION."

No.	Name of species	Germination at control %	Germination in combinations %
1.	*Lycium europeum* L.	10	100
	Cocculus pendulus (Forsk.) Diels.	0	0
2.	*Aerva pseuaotomentosa* Blatt. & Hall.	10	70
	Heliotropium subulatum (Hoechst.) Vatke.	0	0
3.	*Periploca aphylla* Decene.	0	40
	Commiphora mukul (Hk.f. ex Stocks) Engler.	0	0
4.	*Indigofera oblongifolia* Forsk.	0	30
	Corchorus trilocularis L.	0	0
5.	*Salvadora oleoides* Decne.	0	0
	Salvadora persica L.	70	100
6.	*Aerva javanica* (Burm. f.) Juss.	0	0
	Achyranthes aspera L.	70	100
7.	*Aristolochia bracteata* Retz.	0	0
	Mollugo hirta Thnb.	80	100
8.	*Tephrosia strigosa* (dalz.) Sant. & Mah.	0	20
	Convolvulus glomeratus Choisy.	0	0
9.	*Aristolochia bracteata* Retz.	0	0
	Inaigofera oblongifolia orsk.	0	10
10.	*Achyranthes aspera* L.	70	80
	Abutilon fruticosum Guill.	0	0
11.	*Achyranthes aspera* L.	70	80
	Heliotropium ophioglossum Stocks.	0	0
12.	*Blepharis sindica* T. And.	100	100
	Indigofera oblongifolia Forsk.	0	10
13.	*Cassia holosericea* Fres.	0	10
	Gynandropsis gynandra (L.) Briq.	0	0
14.	*Commiphora mukul* (Hk.f.ex Stocks) Engler.	0	10
	Grewia tenax (Forsk.)	0	0
15.	*Commiphora mukul* A. & S. (Hk.f.ex Stocks) Engler	0	10
	Gossypium stocksii Mast.	0	0
16.	*Datura alba* Nees.	10	20
	Schweinfurthia papilionacea (Brum. f) Boiss.	0	0
17.	*Indigofera oblongifolia* Forsk.	0	10
	Mimosa hamata Willd.	10	10
18.	*Indigofera oblongifolia* Forsk.	0	10
	Solanum xanthocarpum Schrad.	0	0
19.	*Indigofera oblongifolia* Forsk.	0	10
	Lycium europeum L.	10	10
20.	*Lycium europeum* L.	10	20
	Gossypium stocksii Mast.	0	0
21.	*Mollugo hirta* Thunb.	80	20
	Acacia nilotica (Lamk.) Willd.	0	0
22.	*Periploca aphylla* Decene.	0	10
	Acacia senegal Willd.	70	70
23.	*Periploca aphylla* Decene.	0	10
	Grewia tenax (Forsk.) A. & S.	0	0
24.	*Tephrosia strigosa* (Dalz.) Sant. & Mah.	0	10
	Cassia holosericea Fres.	0	0
25.	*Withania somnifera* (L.) Dunal.	0	10
	Calotropis procera (Willd.) R. Br.	0	0
26.	*Tephrosia strigosa* (Dalz.) Sant. & Mah.	0	10
	Leucas urticaefolia (Valg.) Rr. B.	0	0
27.	*Cassia holosericea* Fres.	0	10
	Blepharis sindica T. And.	100	100

One-way Stimulation.—This means that the chemicals released from the seeds of a species stimulated the germination of another species. Twenty-seven combinations belonged to this type of interaction (Table 2).

Mutual Inhibition.—When the seeds of two species placed together inhibit each other, the inhibition is designated as mutual inhibition. Eighteen combinations were of this type. (Table 3).

Mutual Stimulation.—When the seeds of two species promote germination of one another, the stimulation is called mutual stimulation. Five combinations indicated this type of interaction (Table 4).

Both-way Interaction.—In this type of interaction the seeds of one species inhibits the germination of another species, which on the other hand promotes germination of the first one. In other words, both the beneficial as well as the antagonistic interactions occur at the same time. Six combinations were of this type (Table 5).

The predominant chemical interaction in this study was one-way inhibition, the number of combinations being 44 out of the 100 positive combinations. The next important interaction was one-way stimulation having 27 combinations. If both one-way inhibition and mutual inhibition are put together, the number of total inhibitory combinations would be 62.

Classification of Chemically Interacting Species

So far the discussion was centered around the classification of types of chemical interactions. Now it seems appropriate to classify the individual species according to the predominant interaction manifested when they were combined with other species.

As mentioned earlier, 58 species were tried in this study, but only 51 species were found to be positively interacting. These 51 species have been classified (Table 6) into six distinct groups which are as under:

Exclusively inhibitory (16 species); mostly inhibitory (9 species); exclusively stimulatory (5 species); mostly stimulatory (4 species); mixed type (16 species); interacting both-way (1 species).

This group includes species which did not show any predominant interaction and the number of inhibitory and stimulatory interactions produced by them was more or less equal.

The number of species producing inhibitory interaction, however, is greater than the species producing other types of interactions.

Distribution of Interacting Species in Different Habitats

In order to find out whether or not any one or more habitats contained a great number of reactive species all the 58 species (including negative species) were grouped into habitats of their preference.

TABLE 3.—LIST OF SEED COMBINATIONS SHOWING "MUTUAL INHIBITION."

No	Name of species	Germination at control %	Germination in combinations %
1	*Capparis decidua* Forsk.	60	0
	Lycium europeum L.	10	0
2	*Acacia senegal* Willd.	70	20
	Caparis decidua Forsk.	60	0
3	*Achyranthes aspera* L.	70	20
	Datura alba Nees.	10	0
4	*Heliotropium europeum* L.	50	0
	Indigofera cordifolia Heyene.	30	0
5	*Barleria acanthoides* Wahl.	40	0
	Cassia italica Mill. Lamk. ex F W Andr.	10	0
6	*Citrullus colocynthis* (L.) Shrad.	90	50
	Cressa cretica L.	40	10
7	*Cressa cretica* L.	40	0
	Datura alba Nees.	10	0
8	*Barleria acanthoides* Vahl.	40	0
	Lycium europeum L.	10	0
9	*Atriplex stocksii* (Wt.) Boiss.	40	10
	Cressa cretica L.	40	10
10	*Cressa cretica* L.	40	10
	Suaeda monoica Forsk. ex. Gmel.	30	10
11	*Haloxylon recurvum* (Moq.) Bunge.	30	0
	Suaeda nudiflora (Willd.) Moq.	10	0
12	*Atriplex stocksii* (Wt.) Boiss.	40	20
	Citrullus colocynthis (L.) Shrad.	90	60
13	*Atriplex stocksii* (Wt.) Boiss.	40	20
	Haloxylon recurvum (Moq) Bunge.	30	20
14	*Indigofera cordifolia* Heyene.	30	10
	Trianthems pentandra L.	10	0
15	*Pteropyrum oliveri* J. & S.	20	0
	Suaeda monoica Forsk. ex Gmel.	30	0
16	*Pteropyrum oliveri* J. & S.	20	0
	Suaeda nudiflora (Willd.) Moq.	10	0
17	*Pteropyrum oliveri* J. & S.	20	10
	Salvadora persica L.	70	60
18	*Pteropyrum oliveri* J. & S.	20	10
	Lycium europeum L.	10	0

TABLE 4.—LIST OF SEED COMBINATIONS SHOWING "MUTUAL STIMULATION."

No.	Name of species	Germination at control %	Germination in combinations %
1	*Haloxylon recurvum* (Moq.) Bunge.	30	100
	Suaeda monoica Forsk. ex. Gmen.	30	40
2	*Abutilon indicum* (L.) Swt.	0	20
	Achyranthus aspera L.	70	100
3	*Indigofera oblongifolia* Forsk,.	0	10
	Mollugo hirta Thunb.	80	100
4	*Acacia senegal* Willd.	70	80
	Pteropyrum oliveri J. & S.	20	30
5	*Aerva javanica* (Burm f) Juss.	0	10
	Abutilon fruticosum Guill.	0	10

Quite a number of species occur in more than one habitat. The grouping is as follows:-

1. Saline soils: *Haloxylon recurvum, Cressa cretica, Atriplex stocksii, Salvadora persica, Suaeda monoica, Suaeda nudiflora* (All reactive species).

2. Saline sand dunes: *Atriplex stocksii*, *Aerva pseudotomentosa*,* *Citrullus colocynthis*, *Cressa cretica*, *Salvadora persica*, *Suaeda monoica*, *Suaeda nudiflora*, *Heliotropium subulatum*, *Gynandropsis gynandra*.

3. Inland sand dunes (Non Saline): *Aerva pseudotomentosa*,* *Capparis decidua*, *Commiphora mukul*, *Lycium europeum* and *Salvadora oleoides*.

4. *Seasonally flooded low lowlands.—Indigofera oblongifolia*, *Mimosa hamata*, *Mollugo hirta*, *Acacia nilotica*, *Zizyphus nummularia*.*

Waste Lands and Disturbed Areas.—Abutilon fruticosum, *Abutilon indicum*, *Achyranthes aspera*, *Aerva javanica*, *Cassia holosericea*, *Cassia italica*, *Datura alba*, *Heliotropium europeum*, *Mollugo hirta*, *Solanum incanum*,* *Trianthema pentandra*, *Withania somnifera*, *Peganum harmala*, *Amaranthus viridis**, *Aristolochia bracteata*, *Calotropis procera*, *Cleome viscosa*, *Euphorbia granulata*, *Gynandropsis gynandra*, *Solanum xanthocarpum*.

Dry Stream Banks.—Acacia senegal, *Commiphora mukul*, *Periploca aphylla*, *Pteropyrum oliveri*, *Acacia nilotica*, *Grewia tenax*, *Zizyphus nummularia*,* *Cordia rothii*.*

Alluvial Plains.—Capparis decidua, *Blepharis sindica*, *Indigofera cordifolia*, *Lycium europeum*, *Tephrosia strigosa*, *Corchorus depressus*, *Corchorus trilocularis*, *Cordia rothii*,* *Cleome brachycarpa*,* *Euphorbia granulata*, *Gossypium stocksii*, *Grewia tenax*, *Heliotropium ophioglossum*, *Leucas urticaefolia*, *Salvadora oleoides*, *Salvia aegyptiaca*,* *Schweinfurthia papilionacea*, *Schweinfurthia pedicellata*.

Calcarious Hills.—Acacia senegal, *Commiphora mukul*, *Barleria acanthoides*, *Breweria latifolia*, *Cleome brachycarpa*,* *Cordia rothii*, *Grewia tenax*, *Heliotropium ophioglossum*, *Salvadora oleoides*, *Salvia aegyptiaca*,* *Schweinfurthia pedicellata*.

Climbers of Large Bushes and Trees.—Convolvulus glomeratus, *Cocculus pendulus*.

It is evident from Table 7 that the percentage of chemically reactive species in each habitat is very high, ranging from 72.7% to 100%. On the other hand, if the reactive species in each habitat are expressed as a percentage of total number of reactive species in all habitats, then the plants of waste lands (including weeds) will show the highest number of reactive species. Next in importance would be plants of alluvial plains, saline sand dunes, calcareous hills, saline soils and dry stream banks.

The predominant type of interaction in plants of alluvial plains, saline soils, saline and inland sand dunes was found to be mostly inhibitory. The

TABLE 5.—LIST OF SEED COMBINATIONS SHOWING "BOTH-WAY INTERACTION".

No.	Name of species	Germination at control %	Germination in combination %
1.	*Indigofera cordifolia* Heyene.	30	0
	Mollugo hirta Thunb.	80	100
2.	*Atriplex stocksii* (Wt.) Boiss	40	30
	Inaigofera oblongifolia Forsk.	0	40
3.	*Capparis decidua* Forsk.	60	0
	Commiphora mukul (Hk.f. ex. Stocks) Engler	0	10
4.	*Atriplex stocksii* (Wt.) Boiss.	40	20
	Suaeda monoica Forsk. ex Gmel.	30	40
5.	*Atriplex stocksii* (Wt.) Boiss.	40	10
	Achyranthes aspera L.	70	80
6.	*Withania somnifera* (L.) Dunal.	0	10
	Cassia italica Mill. Lamk. ex F.W. Andr.	10	0

TABLE 6.—CLASSIFICATION OF INTERACTING SPECIES.

Species	No. of combinations tried	No. of positive combinations	No. of combinations showing one-way inhibition	No. of combinations showing mutual inhibition	No. of combinations showing one-way stimulation	No. of combinations showing mutual stimulation	No. of combin tions showing a both-way interaction
Exclusively Inhibitory							
1. *Barleria acanthoides* vahl.	3	2	—	2	—	—	—
2. *Breweria latifolia* (Hochst. & Steud.) Benth.	3	2	2	—	—	—	—
3. *Citrullus colocynthis* (L.) Schrad.	5	3	1	2	—	—	—
4. *Cleome viscosa* L.	5	1	1	—	—	—	—
5. *Corchorus depressus* (L.) Stocks.	9	3	3	—	—	—	—
6. *Cressa cretica* L.	9	3	—	3	—	—	—
7. *Datura alba* Nees.	6	2	—	2	—	—	—
8. *Euphorbia granulata* Forsk.	4	1	1	—	—	—	—
9. *Heliotropium europeum* L.	3	1	—	1	—	—	—
10. *Peganum harmala* L.	7	2	2	—	—	—	—
11. *Periploca aphylla* Decene.	4	1	1	—	—	—	—
12. *Salvadorapersica* L.	4	1	1	—	—	—	—
13. *Schweinfurthia pedicellata* (T. And.) Btth.	5	1	1	—	—	—	—
14. *Suaedanudiflora* (wild) Moq.	6	6	4	2	—	—	—
15. *Tephrosia strigosa* (Dalz.) Sant. & Mah.	7	1	1	—	—	—	—
16. *Trianthema pentandra* L.	5	1	—	1	—	—	—

*Negative species

(*Continued*)

(Table 6—Contd.)

1	2	3	4	5	6	7	8
Mostly Inhibitory							
1. *Capparis decidua* Forsk.	8	3	—	2	—	—	1
2. *Cassia holosericea* Fres.	11	4	3	—	1	—	—
3. *Convolvulus glomeratus*, choisy.	8	4	3	—	1	—	—
4. *Haloxylon recurvum* (Moq.) Bunge.	4	3	—	2	—	1	—
5. *Heliotropium subulatum* (Hochst) Vatke.	8	3	2	—	1	—	—
6. *Indigofera cordifolia* Heyene.	9	3	—	2	—	—	1
7. *Lycium europeum* L.	12	4	—	3	1	—	—
8. *Pteropyrum oliveri* J. & S.	6	5	—	4	—	1	—
9. *Salvadora oleoides* Decne.	4	4	3	—	1	—	—
Exclusively Stimulating							
1. *Abutilon indicum* (L.) Swt.	6	1	—	—	—	1	—
2. *Aerva javanica* (Burm. f.) Juss	5	2	—	—	1	1	—
3. *Blepharis sindica* T. And.	8	2	—	—	2	—	—
4. *Heliotropium ophioglossum* stocks.	4	1	—	—	1	—	—
5. *Mimosa hamata* Willd.	6	1	—	—	1	—	—
Mostly Stimulatory							
1. *Abutilon fruticosum* Guill.	6	3	1	—	1	1	—
2. *Acacia senegal* Willd.	8	3	—	1	1	1	—
3. *Gossypium stocksii* Mast.	6	3	1	—	2	—	—
4. *Grewia tenax* (Forsk) A. & S.	6	3	1	—	2	—	—
Mixed Type							
1. *Acacia nilotica* (Lamk) Willd.	2	2	1	—	1	—	—
2. *Achyranthes aspera* L.	6	3	—	1	—	1	1
3. *Aristolochia bracteata* Retz.	5	4	2	—	2	—	—
4. *Atriplex stocksii* (Wt.) Boiss.	8	6	—	3	—	—	3
5. *Calotropis procera* (Willd.) R. Br.	6	2	1	—	1	—	—
6. *Cassia italica* Mill.	4	2	—	1	—	—	1
7. *Cocculus pendulus* (Forsk) Diels.	5	2	1	—	1	—	—
8. *Commiphora mukul* (Hk. F. ex Stocks) Engler	9	3	1	—	1	—	1
9. *Corchorus trilocularis* L.	5	2	1	—	1	—	—
10. *Gynandropsis gynandra* (L) Briq.	7	2	1	—	1	—	—
11. *Indigofera oblongifolia* Forsk.	13	3	1	—	—	1	1
12. *Leucas urticaefolia* (Vah.) R. Br.	5	2	1	—	1	—	—
13. *Mollugo hirta Thunb.*	4	2	—	—	—	1	1
14. *Solanum xanthocarpum* Schrad.	9	2	1	—	1	—	—
15. *Schweinfurthia papilionacea* (Burm.f.) Boiss.	5	2	1	—	1	—	—
16. *Suaeda monoica* Forsk.	5	4	—	2	—	1	1
Interacting Both-way							
1. *Withania somnifera* (L.) Dunal.	6	1	—	—	—	—	1

plants of waste lands, dry stream banks and calcarious hills contained an equal proportion of inhibitory and stimulatory species. In plants of seasonally flooded lowlands, the predominant interaction was mostly mixed type, i.e. the plants produced both inhibitory and stimulatory interactions. No habitat, however, contained exclusively or mostly stimulatory species.

Discussion

The phenomena of chemical interactions between seeds of native species seems to be quite widespread. Out of 58 species that were studied, the seeds of 51 species were found to be chemically interacting.

The occurrence of chemical substances in the seeds of a number of native plants has been indicated earlier.[5,6,7] The chemical substances delayed the germination of the seeds. Several such seeds have been used in the present study. The chemical substances were shown to cause seed dormancy, but in the present work they appear to be affecting the seeds of other species in their vicinity.

Evenari[4] enumerated a number of combinations of seeds of weeds and crops, in which chemical interactions occurred. However, only one type of interaction, i.e. one-way inhibition, was reported by him. This paper shows for the first time the existence of five distinct types of interactions. It can now be said that the interactions between seeds are not entirely hostile.

TABLE 7.—DISTRIBUTION OF PREDOMINANT TYPES OF INTERACTION IN DIFFERENT HABITATS.

Classification of plants according to habitat	No. of species tried	No. of reactive species	Percentage of reactive species	Predominant type of interaction
1. Plants of saline soils	6	6	100.0	Most inhibitory
2. Plants of saline sand dunes	9	8	88.8	
3. Plants of inland sand dunes	5	4	80.0	
4. Plants of alluvial plains	18	15	83.0	
5. Plants of waste lands, weeds, etc.	20	18	90.0	Almost equal No. of inhibitory and stimulatory interactions
6. Calcarious hills	11	8	72.7	
7. Dry stream banks	8	6	75.0	
8. Seasonally flooded lowlands	5	4	80.0	Mostly mixed type
9. Climbers of large bushes and trees	2	2	100.0	Inhibitory-cum-mixed type

The predominance of inhibitory types of interactions seem to be largely due to weeds (including plants of waste lands) and halophytes, which figure prominently in exclusively inhibitory and mostly inhibitory groups in Table 6. The number of species of weeds and halophytes is 14 out of 25 species listed in the two inhibitory groups.

While at the present moment, it is very difficult to say what kinds of chemical substances the seeds of weeds may contain, the seeds of halophytes at least seem more likely to contain salts, particularly sodium. Mayer and Poljakoff–Mayber[8] have recently reported that certain halophytes accumulate salts in the dispersal units in sufficient quantity to inhibit germination of their own seeds.

The substances promoting germination released from seeds are not known. It is quite possible that certain amino acids and sugars may be involved in stimulatory interactions or even in a nutritional way. Borner[2] reported that some seeds excrete such substances. It is also possible that an inhibitor in very low concentration may actually promote germination.

The occurrence of species interacting chemically or the distribution of any one type of interaction in a given habitat may have wide ecological implications. For example, predominantly inhibitory interaction in any one habitat may result in an increased competition between the seeds at germination level and a reduced competition between the seedlings emerged from the seeds. This will lead to lesser pressure of plants on the environmental resources and hence slower rates of vegetational development through succession. Just the reverse will be the case in habitats having stimulatory interactions. An almost equal distribution of inhibitory and stimulatory species or a mixed type of interaction in a given habitat will tend to produce a balanced relation in terms of competition between seeds and seedlings, and the rate of succession. This will also help to explain the sequence of successional stages in a habitat and the resultant fluctuations in the pressure of plants on environmental resources.

To support this argument, quantitative data on competition and rates of succession are not available for the local plant communities. But observations on the native vegetation reveals that the rate of succession in saline habitats is rather slow, while it is slightly fast in seasonally flooded lowlands and dry stream banks. The former habitats contain mostly inhibitory species and the latter habitats have an equal number of inhibitory and stimulatory species.

In arid lands, however, faster rates of succession and greater pressure on environmental resources, particularly nutrients and water, are not desirable because both nutrients and water are limiting factors. Viewed in this perspective the inhibitory interactions in desert plants should be looked upon as an adaptive mechanism. In such habitats as seasonally flooded lowlands and dry stream banks, where soil moisture regime is better than in all other habitats, inhibitory interactions may have no adaptive significance while stimulatory interactions may be even beneficial.

Research involving identification of chemical substances released by the seeds, their effectiveness under different soil conditions and further experimental work on these substances, seems to offer immense opportunities in solving complex phytosociological problems and in elucidating weed-crop relationships.

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