"THE EFFECTS OF WATER POTENTIALS OF SOME MEDIA ON THE AFTER-RIPENING AND GERMINATION OF CARAGANA ARBORESCENS AND CYTISUS AUSTRIACUS SEED"

by

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THE EFFECTS OF WATER POTENTIALS OF SOME MEDIA ON THE AFTER-RIPENING AND GERMINATION OF *Caragana arborescens* AND *Cytisus austriacus* SEED

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ABSTRACT

The mature seeds of *Caragana arborescens* Lam., common caragana and *Cytisus austriacus* L., Austrian broom are dormant. To overcome the dormant condition, caragana seeds may be stratified for 14 days and the Austrian broom seeds for 42 days in a moist medium prior to germination.

A moisture tension which is dependent on water content exists for each medium in which seeds may be after-ripened or germinated. Optimum germination in caragana seeds occurred when the water contents of the medias were adjusted to within the pF range of 1.0 to 4.0 whereas optimum seed germination for Austrian broom occurred in pF range of 1.5 to 3.5. As observed particularly in turface, the seed-water regime for seed after-ripening may differ from that required for seed germination. The water content of the turface of pF 4.0 was sufficient enough to promote after-ripening but was not sufficient to initiate germination in caragana seeds.

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INTRODUCTION

The plant propagator may experience some difficulty in the production of woody ornamental plants from seed. Many woody ornamental seeds, although viable, are dormant and this condition must be overcome prior to germination. The dormancy may be caused by mechanical means such as an impermeable seed coat, or physiological such as chemical inhibition of metabolic activities. Seed dormancy may be advantageous to plants growing in temperate zones, allowing the seed to germinate at a favorable time and place. In the natural habitat, several years may elapse before favorable conditions are attained to overcome the dormant conditions. The plant propagator may induce the seeds to maximum germination by creating the essential combination of natural conditions needed to overcome the dormant condition.

For dormant seeds to germinate, physiological changes of after-ripening, must occur within the seed. Generally, after-ripening is promoted by stratification or the practice of placing seeds in moist layers of a medium. The determination of environmental conditions of water, oxygen and temperature are important for effective after-ripening.

While considerable experimentation has occurred on the effect of water, air, temperature and chemicals for after-ripening and germination, little is known about the physical effect of the medium. The primary medium components used are mineral soils, including sand, peat and processed medium amendments such as perlite, turface and vermiculite. These are used individually or as mixtures. The medium may vary in particle size, composition, nutritive content and reaction. Because the composition of the medium may affect after-ripening and germination, it would be desirable to tailor the medium to obtain uniform results similar to those developed for rooting and container culture.

The objective of the study was to establish an optimum water potential range for some media and to compare the media for after-ripening and germination of two woody ornamental plant species, *Caragana arborescens* Lam. and *Cytisus austriacus* L.

LITERATURE REVIEW

The stratification and germination medium is a disperse, three-phase system consisting of mineral particles, water and air (29). According to Heydecker (27, 28), and Pollock and Manalo (40), the three phases must potentially interact to contribute to seed germination. The medium used must provide adequate pore space for air-water balance, optimum temperature for imbibition of water and to initiate physiological activity within the embryo, and to enable the seedling to emerge without mechanical obstruction. The importance of precision seeding to germination rate and percentage has made it necessary to develop and evaluate the capabilities of the medium to fulfill the necessary criteria (45).

Moisture

The germination of dormant or nondormant seeds is affected primarily by the moisture condition of the medium (7, 11, 12, 35, 43). Lyon, Buckman and Brady (35) describe two forces, adhesion and cohesion, as accounting for temporary fixation of water in the medium. Adhesion is an electrostatic force acting on both internal and external surfaces of the medium solid phase, holding water in a thin film. The adhesive force is prevalent in clay. Cohesion is the attractive force of water molecules for one another within the pore spaces.

A suction is exerted by the hydrophilic colloids within the seed to remove the water held within the medium by adhesion and cohesion (7, 10, 11, 12, 29, 35, 40). Availability of water to the seeds depends upon the moisture characteristics of the soil and the imbibition characteristics of the seed (11, 12). According to Collis-George and Sands (11, 12), the germination behavior of seeds is controlled by water suction and permeability. The water requirements for each species is specific in terms of energy required for suction and rate of water supply, thus it is possible to determine the water regime for each species.

The suction required to remove water from a medium is dependant upon the size of the initial pore spaces and the texture of the medium and the amount of water present in the pore spaces (43). A saturated or wet medium will give up water more readily than a dry or non-saturated medium. In a coarse textured medium such as sand, there are large initial pore space sizes and very little change in pore space size as water is withdrawn and air readily replaced the water. In a fine textured medium such as clay, the initial pore space sizes are smaller and the withdrawal of water results in shrinkage and reduces the pore size. The net result is that greater suction is required to remove water from the finely textured soils.

Many methods have been devised for measuring water potential gradient between the medium and the plants or seeds. Hillel (29), stated that there is no universally accepted method for measuring, computing or expressing the moisture regimes of various media. The relationship of soil water to seed germination can be expressed as a function of percentage moisture (4, 34, 46), water holding capacity (35), and available water (11, 12, 33). In the literature it is generally agreed that the availability of water is dependent on the soil moisture potential rather than the total soil moisture content. Soil moisture potential may be expressed as pF (19), or potential available water. The availability of water differs with each medium.

Medium

The natural soil amendments are sand and peat. Buckman and Brady (7), Hartmann and Kester (26), and Lindquist (34) define sand as particles of rock between 0.05 to 2.0 mm in diameter. Kuenan (32) states that the basic origin of sand is calcium carbonate, aluminum silicate or silicon dioxide. Sand is desirable as an individual medium in a mixture due to a wide range of pore sizes for aeration and drainage. The large particle size and rigid structure of sand make water readily available while maintaining large pore spaces.

Hartmann and Kester (26) define peat as the organic remains of plants which have accumulated in places where decomposition has been retarded by wet conditions. Peat may be classified as woody peat, fibrous peat or sedimentary peat (35). Fibrous peat, composed of sedges, sphagnum mosses and cattails is the most common type used by horticulturists (33, 35, 35). Although fibrous peats are heterogeneous in character, the gravimetric water content is very high, possibly ten times greater than that of mineral soils. A good quality peat is open, porous and supplies adequate aeration. A disadvantage of peat is the loss of fibrous qualities with repeated use (7, 35).

A 1:1 mixture of sand and peat could provide a good germination medium. The sand provides large pore spaces with readily available water whereas peat supplies fibrous bulk for water retention.

The processed media include vermiculite, perlite and turface. Raw vermiculite ore is a micaceous mineral, consisting of many thin layers which entrap air. Barshad (5), characterizes vermiculite chemically as hydrated magnesium-aluminum-iron-silicate. The ore is passed through furnaces at 1093^{o}C converting water into steam thus expanding the layers. The end product is a small, porous, sponge-like, sterile "kernel" (particle). Vermiculite has a water holding capacity up to five times its weight due to the larger interface area. The recommended vermiculite for seed germination is grade No. 4 with a particle size range of 0.75 to 1.0 mm. Vermiculite provides for air and bulk when incorporated into a medium mixture.

A second processed medium is perlite. The grey white material of volcanic origin, is a chemical combination of silicon, aluminum, potassium and sodium oxide (26, 33). Perlite ore is heated in furnaces to approximately 982^{o}C. As in the case of vermiculite, small amounts of water are changed to steam and thus expand the particles. The large particle size and rigid structure of the perlite provide for a wide range of pore sizes for aeration and ease of water removal. The porosity of the individual particles result in an entrapment of water and thus perlite has a greater water holding capacity than sand. Perlite is essentially neutral with a pH of 7.0 to 7.5.

Turface, a montmorillonite clay, is also a processed medium amendment. The raw clay is cut, crushed and ground to particles of uniform size. The particles are then fed to a calcinator at temperatures of 982^{o}C where the careful control of the time and tumbling action produces a particle which allows for air movement and water absorption when used separately or as part of a medium mixture. Turface does not alter in particle size and shape when wetted and it can absorb water equal to its own weight. According to Technical Service Bulletin (2), turface provides a uniform supply of water to the growing plants.

Temperature

Collis-George and Sands (11, 12), stated that a water regime exists between seeds of different species of plants and the medium in which germination occurs. The regime reacts with other factors such as time, temperature and air-supply for after-ripening. Many woody ornamental plants such as *Caragana* (34), *Fraxinus* (51), *Elaeagnus* (13), *Acer* (17, 52), *Rosa* (48), and *Juniperus* (37) require temperatures for after-ripening of approximately 5°C. Giersbach (25), reported that cotoneaster seeds require treatment at two separate temperature ranges for germination to occur. Treatment at 15 to 25°C for three to four months overcomes the seed coat dormancy, followed by temperatures of 1 to 5°C for four months for after-ripening. *Viburnum* requires alternating temperatures between 10 and 30°C to overcome dormancies (22, 30).

Time

The length of after-ripening time varies with species. Linquist (34), stratified *Caragana arborescens* seeds for fifteen days. *Acer saccharum* and *Acer ginnala* (17, 52) require 30 days for after-ripening whereas *Viburnum* (22, 30) and cotoneaster (25) require two winters in natural habitat or over 110 days under laboratory conditions for germination to occur.

Physiological Changes

In a dormant or nongrowing condition, the metabolic rate of seeds is low (14, 31, 41, 42). As the after-ripening process begins, physiological changes requiring oxygen occur within the embryo. Eckerson (18), studying after-ripening of *Crataegus mollis* seeds, reported an increase in oxidase activity, reduction of fat content with an increase in soluble sugars and increased energy activity as measured in increased metabolic temperature. The increase in respiration in *Juniperus* seeds resulted in a doubling of catalase activity (37). Dumbroff and Webb (17, 52), stated that the respiratory rates of seeds of *Acer saccharum* and *Acer ginnala* are correlated to their water uptake. Dormant cereal seeds show a greater initial uptake of oxygen than nondormant seeds (36). Due to specific requirements of individual species, these scattered pieces of work still leave the propagator wondering if an optimum range of available water exists for the after-ripening and germination of seeds.

METHODS AND MATERIALS

The objective of the study was to establish a pF range for some media and to compare the media for after-ripening and germination of the two woody ornamental plant species, *Caragana arborescens* and *Cytisus austriacus*.

The experimental procedure was subdivided as follows:

I. Determination of water potential pF - water content relationship for each medium.

II. After-ripening and germination of common caragana, *Caragana arborescens*.

III. After-ripening and germination of Austrian broom, *Cytisus austriacus*.

The six natural and processed medium amendments used were:

1. Sand - local origin, 0.5 to 1.0 mm particle size.
2. Peat - Manitoba native fibrous peat moss, partly decomposed.
3. Sand-peat mixture - 1:1 mixture by volume.
4. Vermiculite - Terra-lite, commercial grade No. 3.
5. Perlite - Concrete aggregate.
6. Turface - Wyandotte Mulch.

Moisture Characteristics

The objective of this experiment was to determine the matrix potential of available water (pF) for each medium treatment. pF is the log moisture potential when moisture potential is given in equivalent cm of water, e.g., 1 atmosphere = 1033 cm of water ≃ pF 3.0. A treatment constitutes a definite volume of water (ml), added to a specific weight of medium (gm). Since the specific gravity of water is 1.0, the water to medium ratio is actually a weight of water to weight of medium ratio.

The procedure employed was similar to that outlined by Fawcett and Collis-George (19). The hydrophilic properties of filter paper were used to estimate the moisture potentials of soil media. Different grades of filter paper have different hydrophilic properties. This results in a definite pF-water content graph for each grade of filter paper. In this study, Whatman No. 42 filter paper was used. The filter paper was allowed sufficient time to equilibrate to the moisture in the medium and pF values were estimated from the standard graph for Whatman No. 42 filter paper (19).

A definite weight of medium was thoroughly mixed with a specific volume of water. One half of the medium was put into a plastic container and three pieces of Whatman No. 42 filter paper were placed on the medium. The air-dry weight of the innermost piece of filter paper was recorded immediately prior to being placed in the container. The remaining medium was pressed firmly on top of the filter papers and the containers closed and sealed with masking tape and placed in a cold room for fourteen days at a temperature of $1.6 \pm 0.5^{o}C$. After fourteen days, the containers were opened, the outer two filter papers were discarded and the innermost paper was weighed immediately. The increase in moisture percentage of air-dry weight was calculated and converted to a pF value by the Fawcett and Collis-George method (19).

The Soil Science Department, University of Manitoba, determined the pF-water content relationship of the Whatman No. 42 filter paper using a pressure membrane apparatus. The pF water content relationship was identical to that of Fawcett and Collis-George (19).

Several types of cardboard and plastic containers were tested for water retention. The eventual choice of container was a 10 oz plastic pack No. 6810, with a capacity of 300 ml.

Prior to experimentation, the sand was screened for particle size 0.5 to 1.0 mm, washed and leached with warm water to remove foreign debris. The pH of the sand was 7.1 as determined by a Fisher Accumet pH meter. Sand was oven dried at 200°C for 24 hours prior to use. The peat was screened by using a 3.0 mm screen and was washed and leached. A filter paper lined Buckner Funnel was used to suction dry the peat. Prior to using the peat, the peat was further dried by spreading out to air dry for 24 hours. The pH of the peat was 6.9 as determined by a Fisher Accumet pH meter.

The sand-peat, 1:1 mixture was prepared by mixing equal volumes of cleaned sand and peat. The turface, vermiculite and perlite were used directly from the manufacturers bags.

The individual pF water content relationship for each medium was determined by adding a definite volume (ml) or weight (gm) of water to either 300 gm of sand, 25 gm of peat, 50 gm of sand-peat mixture, 15 gm of perlite, 75 gm of turface or 15 gm of vermiculite. The specific weight of each treatment medium is approximately equivalent to 250 cc of volume. For each medium, a range from 0.0 water content to saturation was covered.

After-ripening and Germination of *Caragana arborescens*

The objective was to determine the effect on the after-ripening and germination of *Caragana arborescens* seed when stratified in sand, peat, 1:1 sand-peat mixture and turface and to determine the optimum pF range for seed after-ripening and germination in each medium.

The *Caragana arborescens* seeds were collected on the University of Manitoba campus during the summers of 1969 and 1970. Immature and damaged seeds were culled out by visual inspection and water flotation and discarded. The seeds were stored in a cold storage room at an approximate temperature of 5°C.

After the pF values were determined and a pF graph was constructed for each medium, eight levels of water (ml) were used for seed treatments for after-ripening. Each trial had two controls, one wet where the seeds were immersed in water and one dry where the seeds were placed in an air-dry medium for the duration of the stratification period. Each treatment was replicated 12 times.

The specific amounts of water added to each medium appear in Table I.

Table I. The amount of water (ml) added to each medium for after-ripening caragana seeds.

		Treatments									
	Media	1	2	3	4	5	6	7	8	9	10
I.	Sand	4	6	8	12	16	20	40	50	0	imm.
II.	Turface I	15	20	30	35	40	45	55	60	0	imm.
III.	Turface II	15	20	30	35	40	45	55	50	0	imm.
IV.	Peat	25	30	37.5	50	62.5	75	87.5	100	0	imm.
V.	Sand-peat	5	10	15	20	25	30	35	40	0	imm.

Turface I - no additional water added prior to germination.
Turface II - additional water was added prior to germination.
imm. - immersed - the seeds are completely immersed in water.

Preliminary studies have indicated that the amount of water required for stratification was not sufficient for germination at low moisture levels. Prior to germination, water was added to treatments with less than a mean level of water for sand, peat and sand-peat mixtures to attain the mean water level. Mean level was in the pF range of approximately 1.5 to 2.0 for the media. In the case of turface, a large proportion of the water was held at high suction (high pF). This meant that at the mean water level, the pF value was approximately 4, i.e., the dry end of the available water range. Therefore, for the turface II treatment, 45 ml of water was added. This gave a pF value of approximately 1.3.

The criteria for germination was the emergence of the radicle, and germination counts were based on the emergence over a two week period. The seeds were germinated in closed containers at a temperature of 20°C.

After-ripening and germination of *Cytisus austriacus*

The objective was to determine the optimum pF range needed to bring about after-ripening and germination of *Cytisus austriacus* seed when stratified in peat, sand-peat mixture, perlite and vermiculite.

The Austrian broom seeds were collected at the University of Manitoba Arboretum during the fall of 1969. The seed lot was variable and many seeds were discarded after visual inspection and water flotation, only ripe, plump seeds were used for experimentation. The seeds were stored in a cold room at an approximate temperature of 5°C until required for experiments.

As in the case of caragana after-ripening, pF graphs of peat, sand-peat mixture, perlite and vermiculite were used to choose eight treatment levels per medium. Wet and dry controls were used for each medium. The seeds were prepared for after-ripening and stored in a cold room for 42 days at a temperature of 1.6 ± 0.05°C. Treatment water levels used for each medium are shown in Table II.

Table II. The amounts of water (ml) added to each medium for after-ripening of Austrian broom.

		Treatment (water in ml)									
	Media	1	2	3	4	5	6	7	8	9	10
I.	Vermiculite	1	3	10	20	30	40	50	60	0	immersed
II.	Peat	25	30	37.5	50	62.5	75	87.5	100	0	immersed
III.	Sand-peat	5	10	15	20	25	30	35	40	0	immersed
IV.	Perlite	1	2	3	4	10	20	30	40	0	immersed

As in the experiment with caragana seeds, water was added to some of the treatments prior to germination. The treatments with a water content below the mean amount for each medium, had sufficient water added to attain the average level.

The criteria for germination was the same for *Caragana arborescens*.

RESULTS AND DISCUSSION

Moisture Characteristics

Water availability of a medium is related to moisture potential. pF is a convenient method of expressing moisture potential. The pF range is 0 to 7.0 where 0 represents a totally saturated medium and 7 expresses a dry medium.

The pF values of each medium were estimated from a table of values and a graph (19, 43). The values are based on the moisture characteristics of Whatman No. 42 filter paper. The pF values were conversions from the moisture content of filter paper which was expressed as a percent of oven-dry weight as indicated in Figure 1. According to Fawcett and Collis-George (19), error due to calibration of the filter paper is approximately 1%. Because of the limited deviation from the normal curve for the filter paper, this method is a fairly simple, accurate method of determining water potential.

Data in Table III are examples of the relationship between moisture content and pF values in sand. The percentage of the weight increase of the centre filter paper as compared to the initial weight, constitutes the moisture content.

Moisture content - pF relationships of peat, sand-peat mixture, vermiculite, perlite and turface appear in the Appendix Tables 1 to 6. These values were used to construct a graph, Figure 2. The graph represents the pF values as a function of the treatment level of water, g water/g media (Dry weight) x 10.

The relative change in pF per unit water addition to the medium

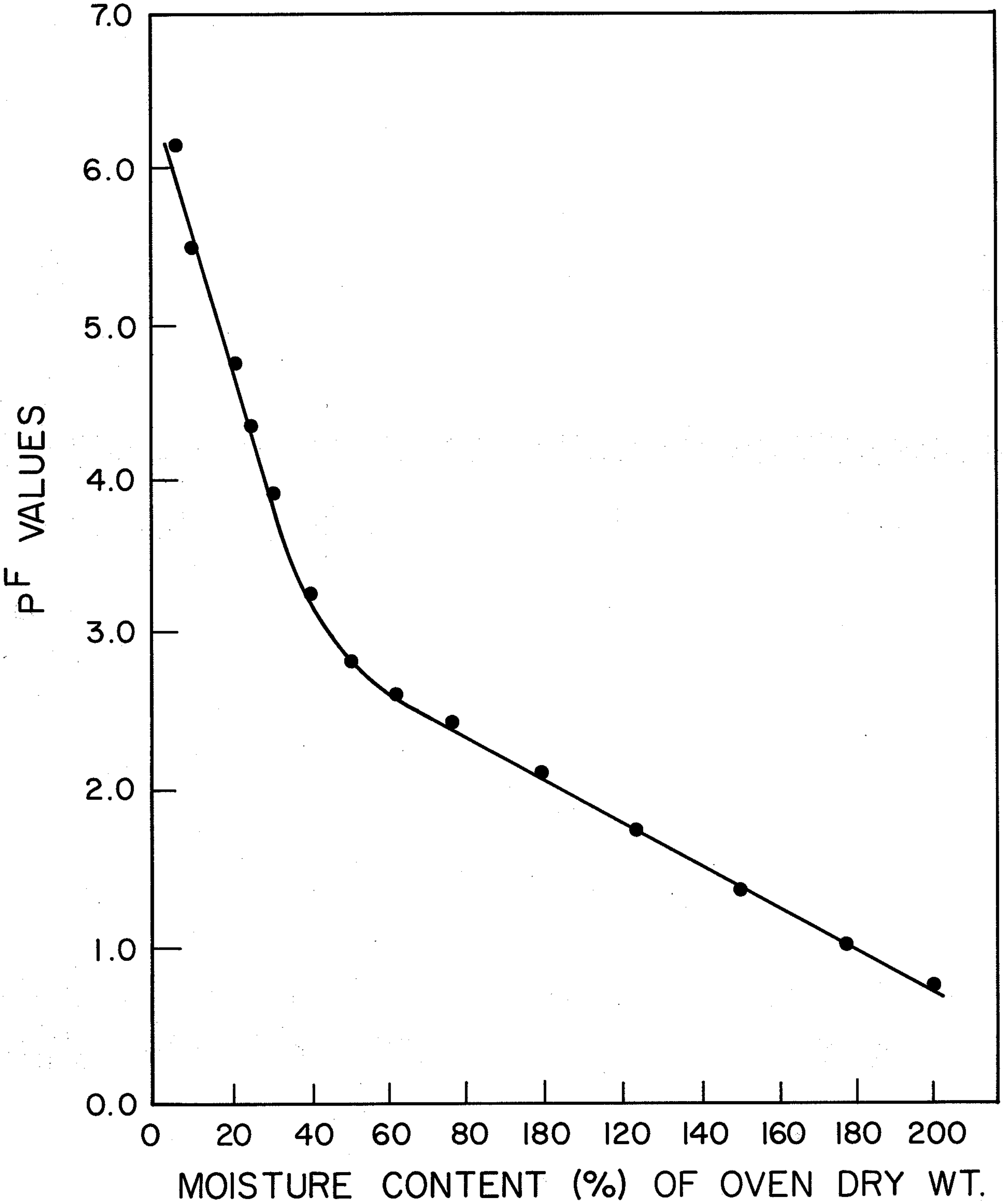

Fig. I The P^F as related to the moisture content (%) of oven dry weight of Whatman No. 42 filter paper as taken from Fawcett R.G. and N. Collis – George (19)

Table III. The relationship of the percentage moisture content to pF values in sand.

g water/g media (D.W.) x 10	Moisture content (%) of oven dry filter paper	pF value
.03	14.95	5.15
.07	20.31	4.75
.10	26.52	4.25
.13	34.03	3.70
.17	40.94	3.30
.20	69.87	2.52
.27	118.91	1.85
.33	136.59	1.60
.40	146.53	1.43
.47	149.06	1.39
.53	158.26	1.25
.60	164.21	1.16
.67	169.21	1.13
1.00	174.48	1.05
1.33	176.58	1.00
1.67	176.97	1.00
2.00	180.64	.98
2.33	182.54	.98
F.C. 3.00	187.91	.97

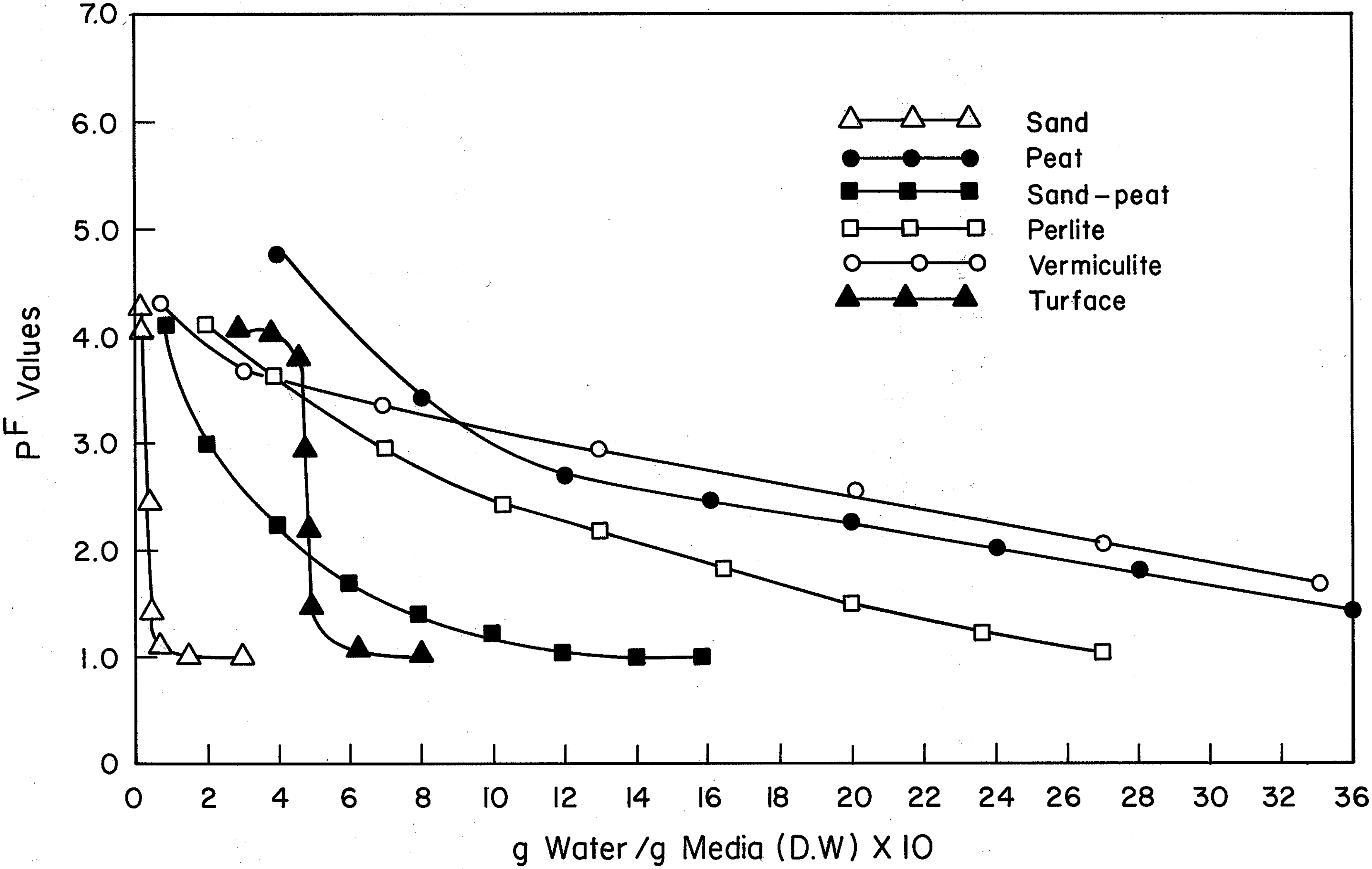

Fig. 2 The relationship between unit of water additions to dry weight of media X 10 and the P^F of the media

is indicative of water availability of the medium, Figure 2. A large change in pF related to a small change in unit water addition to the medium indicated that the medium released water readily. There was minimal water retention and little force would be required to remove the water from the medium. A small change in pF related to a large change in unit water addition indicated a greater water retention and less water availability in the medium.

Two forces account for the temporary fixation of water in the medium. Adhesion is the attraction of solid surfaces for water molecules and is only operative at solid-liquid interfaces. The greater the interface area, the greater the water retention. A second force is an electrostatic attraction of water molecules for charged media particles. As a result of electrostatic charge on media particles and the dipole nature of water molecules, water becomes more organized even at a distance from the media particle. Water molecules are electrostatically bound to other water molecules within pore spaces. Water held by these forces not only can keep the smaller capillary pores within the medium entirely full but also maintains thick films of water in the pores. When the medium is near saturation, it would be easy to remove water but as the moisture content decreases, greater force would be necessary to remove water.

There was a large change in pF in sand, pF 4.1 to 1.0, as related to a small change in unit water addition, 0.03 to 3.00 g water/10 g (D.W.) sand. Water was readily available from the sand and there was little water retention. The large initial pore space size and minimum change in pore space size as water is withdrawn could account for the readily available water in sand. Sand particles have little electrostatic