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ABSTRACT. Twenty-nine species of the genera Amorpha, Dalea, Petalostemon and Psoralea are treated. Taxonomic interpretations are summarized in conventional diagnoses. The nomenclature of the species is reviewed. Illustrations and distributional maps are presented.

The Psoraleae comprise a tribe of papilionaceous legumes. They are typically glandular-dotted and possess 1-(2)-seeded, essentially indehiscent pods. Twenty-nine species are herein recognized for the north-central states.

This treatment (one of a series: Isely, 1951, 1955, 1958; Welsh, 1960) includes specific delimitations and diagnoses, geographic distributions, habitat characteristics, and nomenclatural identity. The data are based upon herbarium specimens, literature, and the author's field experience extending over a period of some fifteen years in the area covered.

Most of the Psoraleae in the north-central states are species whose distribution extends considerably beyond the geographical area under consideration. Some of them, although distinctive and easily characterized in the north-central states, represent segments of incompletely understood complexes. Inasmuch as chief attention has been given to these species as they occur in the north-central United States, circumscriptio, in some instances, may be somewhat provincial. This is a limitation besetting any taxonomic study consigned to a given political area.

A number of the taxa treated are diverse phenotypically. Such variance must naturally be considered critically in the evaluation of specific limits. However, a formalized treatment of subspecific categories is not included in this paper. The author feels that the characterization on an observational basis of geographic races or conspicuous phenotypes as subspecies, varieties or forms is often spurious and misleading. Considering the biological complexities which are usually involved, the delimitation of subspecific categories falls most properly within the province of detailed investigations of individual specific complexes. Such studies employing the necessary methodology and tools (and a wide variety are now available to taxonomists) can interpret on a genetic basis the significance of the various phenotypes exhibited by a species. When data are obtained, the delimitation and characterization of subspecific categories

1 Journal Paper No. J-4271 of the Iowa Agricultural and Home Economics Experiment Station. Project No. 1073.

2 Illustrations by Frances Fenske.
may not only be proper, but can realistically portray the nature of infra-specific variance. The present study has not been of this type.

In order to abbreviate verbal discussion concerning nomenclature, numeral designations following author citation of binomials are employed to indicate the degree to which name utilization has been verified. They are as follows: "1" type specimen or photograph of same examined, "2" original description examined, "3" name utilization follows that of another author who has examined an original specimen or type, "4" name utilization follows that currently accepted; typification not verified. The designations "1, 2, 3," "1, 2," and "2, 3" indicate congruity between the sources of information indicated.

The synonymy is functional rather than complete; it is essentially limited to names which have been used in 20th century treatments, and for elements of the species found in the north-central states. In a few instances, classical synonyms are enumerated, particularly if such names are still frequently extant on herbarium sheets. Likewise, the synonymy is extended beyond the geographic area concerned when this facilitates defining the species.

Acknowledgments

During the course of this study, herbarium material from the following institutions was examined: Missouri Botanical Garden; U. S. National Museum; Iowa State University (Ames); State University of Iowa (Iowa City); Kansas State University; University of Minnesota, University of Illinois; University of Indiana; North Dakota State College; South Dakota State College; University of South Dakota; and University of Nebraska. In addition, type material or photographs were made available by the New York Botanical Garden, the Gray Herbarium of Harvard University, and the Philadelphia Academy of Natural Sciences. Thanks are extended to the respective curators. Special acknowledgment should be rendered to Dr. Walter Benner of the Philadelphia Academy of Natural Sciences. Dr. Benner was exceedingly helpful in providing information concerning Pursh and Nuttall material housed by his institution.

PSORALEAE

Perennial herbs and shrubs (and one annual). Plants glandular-dotted. Leaves odd-pinnate or palmately foliolate. Stipules usually inconspicuous, lanceolate. Inflorescences racemose or spicate, usually terminal. Bracts various, subtending a single flower, or 2–3 (Psoralea). Calyx gamosepalous, variously toothed. Corolla papilionaceous or modified. Stamens 5, or 9–10, diadelphous or monadelphous. Fruit 1–(2) seeded, usually short, included within or exserted from calyx, usually asymmetric, indehiscent or breaking irregularly.

The delimitation of the Psoraleae and the putative relationships of the genera have previously been considered (Isely, 1958).
Key to Genera

1. Plants woody; corolla consisting of only a single petal, the standard.  
   **Amorpha**

1. Plants herbaceous; corolla of 5 petals or petal-like structures.

2. Flowers 2—3 to a bract; petals free from androecium; pod usually exserted from calyx; leaves palmately compound or pinnately trifoliate.  
   **Psoralea**

2. Flowers 1 per bract; claws of four of the petals adnate to androecium; pod included in calyx or slightly exserted; leaves pinnate with more than 3 leaflets (except one species, Dalea jamesii).

3. Functional stamens 9—10; wings and keel arising from side of stamen tube.  
   **Dalea**

3. Functional stamens 5; petaloid structures arising at apex of stamen tube.  
   **Petalostemon**

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**Amorpha L.**

Shrubby or suffrutescent. Leaves odd-pinnate with numerous leaflets. Stipules small, quickly deciduous; stipels likewise. Rachis frequently glandular at base of leaflets. Flowers in spike-like, usually terminal racemes. Flowers with a single evanescent bract. Corolla consisting of only the purple to blue standard which is somewhat rolled around stamen column in bud. Wings and keel absent. Stamens 10, free above, and exceeding standard. Pod exserted from calyx, asymmetric to lunate, beaked, usually conspicuously glandular, 1 or 2-seeded.

Chromosome base number $x = 10$ as per determinations on four species (Darlington and Wylie, 1955).

**Amorpha** is an American genus of approximately 20 species, perhaps centering in the southern United States. Among papilionaceous legumes, it is anomalous in possessing only a single petal. It would appear to possess closest affinities with the less well known Eysenhardtia and Parryella of the southwest; the former is apetalous.

**Amorpha** is the current subject of monographic investigation by another author. Pending eventual availability of these studies (and since much of the herbarium material is in use), a detailed evaluation of the north-central states complexes is not herein attempted.

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Key to Species

1. Plants tall shrubs 2—5 m high; leaflets 2 cm or more in length; fruit 6—8 mm long.  
   **A. fruticosa**
1. Plant undershrubs less than 1 m high; leaflets 0.7—1.0 (1.5) cm in length; fruit 4—6 mm long.

2. Inflorescences solitary, essentially unbranched at stem tips; stems and leaves almost entirely glabrous. A. nana

2. Inflorescences clustered or branched; stems and usually leaves puberulent to canescent.

3. Leaves densely canescent to strigose; calyx lobes shorter than tube; widely distributed species. A. canescens

3. Leaves glabrous to inconspicuously ciliate or slightly puberulous; calyx lobes nearly equalling tube; endemic species of southwestern Missouri. A. brachycarpa

Amorpha brachycarpa Palmer

Low subshrub. Stems puberulous to thinly canescent. Leaves nearly sessile with 10—20 pairs of ovate-elliptic leaflets; rachis puberulous and leaflets somewhat ciliate but otherwise glabrous. Flowering racemes clustered above leaves. Calyx about 3.5 mm long, puberulous, the teeth as long as the tube. Fruit 4—5 mm long, slightly exceeding calyx lobes, ca. 3 mm broad; dorsal margin nearly straight.

Discussion. This species (if it is a species) is apparently a local endemic of southwestern Missouri. It seems to be closely related to A. nana and canescens, superficially resembling the former but having clustered rather than solitary spikes. It lacks the indument of A. canescens and possesses a more deeply toothed calyx.

Nomenclature:

Amorpha brachycarpa Palmer Jour. Arn. Arb. 12:171. 1931. (2)

Amorpha canescens Pursh (Plate I, Map 1)

Low, canescent to glabrate semiligneous shrub with ascending stems, only a few decimeters high and herbaceous in appearance. Leaves short-petioled, with 15—20 pairs of elliptic leaflets. Leaflets elliptic to oblong, mucronate, very short-stalked, usually canescent on both sides but more thinly so above, obscurely glandular under the tomentum. Stipels subulate, brownish, evident on young, unfolding leaflets. Stems terminating in a cluster of crowded spike-like racemes. Bractlets evident in bud, brownish, subulate, 1.5—2 mm. Calyx canescent, ca. 3 mm, the triangular lobes distinct, about 1 mm in length. Standard purple. Anthers orange. Fruit straight, exserted 1—1.5 mm beyond calyx, canescent.

Distribution and habitat. Saskatchewan, New Mexico, Mississippi, Michigan. Typical of prairies and ranges, especially dry slopes, often in sand. Inhabiting prairie openings and open woodlands, and invading roadsides in southern and eastern portions of range. Still relatively abundant in unplowed soil and a conspicuous component of prairie remnants.

Phenology. June—July. Mostly latter portion of June, southern; first half of July, northern.

Variability. Amorpha canescens, as suggested by the name, is ordinarily characterized as being hoary or canescent. Usually it is sufficiently
hairy, especially in prairie habitats, to possess a gray-green coloration and to contrast with the surrounding vegetation. But it is quite variable as to the amount of pubescence—ranging from whitish-canescence to dull green with but little tomentum. This latter extreme has frequently been designated as variety or forma glabrata.

While examining specimens of Amorpha canescens from the north-central states, I attempted arbitrarily to categorize degree of pubescence into five groups ranging from most hoary to glabrate. In general, there appeared to be a greater prevalence of the pubescent forms to the north and west, the more glabrous types to the south. Also, specimens from prairie areas were usually hairier than plants in a woodland habitat (likewise noted in the field). These patterns are probably interrelated in that the species is usually found in wooded rather than prairie habitats in the Missouri Ozarks which include much of the southern portion of the range studied.

Two other factors seem to affect degree of indument observed. One is simply weathering; young leaves possess more pubescence than older ones. Secondly, late season sterile shoots may be glabrate whereas the earlier season foliage was quite hairy.


Discussion. The common name "lead plant" usually has specific reference to Amorpha canescens (in some instances is applied also to A. fruticosa). Torrey and Gray (1838-40) state that the plant was supposed to indicate the presence of lead ore. A. canescens is occasionally found in cultivation as an ornamental.
The Pursh name was probably based upon Nuttall material (Nuttall, 1818. p. 92).

Amorpha canescens Nutt. ex Pursh Fl. Amer. Sept. 467. 1814. (2, 3)
A. canescens Nutt. nom. nud. Fraser Cat. 1813.

Amorpha fruticosa L. (Plate II)

Tall shrub to 5 m. Leaves with 6—15 pairs of leaflets (occasionally more), appearing finely downy or appressed hairy when young, glabrate at maturity. Stipels subulate, conspicuous on young leaves. Leaflets dull, variable in shape, size, and spacing on rachis, ovate, obovate, elliptic to oblong, 1.5—4 times as long as broad. Racemes few in a cluster. Calyx 2.5—3.5 mm, short-toothed, the broadly triangular lateral teeth mostly about 0.5 mm, the subulate ventral tooth 0.5—1.0 mm. Pod strongly exserted from calyx, 6—8 mm long, about 2 mm wide, upwardly curved, strongly glandular.

Distribution and habitat. Saskatchewan, northern Mexico, Florida, Pennsylvania; also naturalized in Eurasia. Bottomland woodlands, along streams, bluffs, margins of lakes, roadsides. In cultivation as an ornamental. Locally common.

Phenology. Flowering peak in north-central states ranging end of May (southern) to July (northern).

Variability. The A. fruticosa complex is diverse genetically. Phenotypic variability is expressed especially in the leaves and the nature of the pubescence. To some extent this variability is geographically correlated, and certain forms have been designated as geographical varieties or segregate species. Much of the variation, however, seems to be reticulate and nongeographical, and is not realistically portrayed by present classifications of the complex. A monographic investigation of Amorpha by another student is current and will doubtless present an improved interpretation of the group.

The predominant form of A. fruticosa in the north-central states possesses appressed pubescence and is usually termed variety angustifolia Pursh (A. fragrans Sweet). It is variable as to leaflet shape, number, and spacing, some representatives matching other named varieties in these characteristics.

Chromosome number. 2n = 40 (Senn, 1938; Turner, 1956).

Discussion. A. fruticosa is variously called False indigo, Indigo-bush, and Lead plant. It is common as an ornamental shrub, not only in the United States but in Europe and to some extent in South America. A number of horticultural forms have become established. It is also employed for windbreak plantings in the plains states.

An insecticidal material (Brett, 1946) has been isolated from this plant and subjected to preliminary tests.

Amorpha nana Nutt. (Plate II, Map 6)

Very low, almost herbaceous, smooth shrubs. Leaflets mostly 12—15
pairs, glabrous and somewhat shiny, elliptic, distinctly glandular below. Spikes solitary, i.e. on separate leafy branches. Flowers purple-blue, fragrant. Calyx glabrous or puberulent, 2.5—3 mm in length; lobes triangular to narrowly lanceolate, ca. 1 mm long. Fruit strongly glandular, straight, short oblong and exserted 2 mm beyond calyx when mature.

Distribution and habitat. Saskatchewan, New Mexico, Iowa. Primarily a plant of the northern plains states, local otherwise. Dry or rocky prairie slopes or knolls, bluffs, native meadows.

Phenology. Flowering peak the first half of June.

Chromosome number. 2n = 20 (Darlington and Wylie, 1955).

Discussion. Nuttall's notes (1818) on the original distribution and abundance of this species may be of interest.

"On the woodless and grassy hills of the river Missouri, from the river Platte to the mountains, growing only from bunches to a foot high. Flowers purplish, blue and fragrant, coming out in the month of May. This very humble plant, often diffused, like heath in Europe, over hundreds of acres in succession, is the only upland shrub apparently capable of withstanding the peculiarities of this climate."

Nomenclature:

Amorpha nana Nutt. Fraser Cat. 1813. (2, 3)
Amorpha microphylla Pursh Fl. Amer. Sept. 466. 1814. (2, 3)

The Fraser Catalogue problem is briefly discussed under Dalea enneandra. The plant described therein seems clearly to be Amorpha nana of subsequent interpretations. However, Torrey and Gray (1838-40; p. 690) cast doubt on identity of material subsequently distributed by Fraser under this name.

Dalea Juss. (Parosela Cav.)

Herbs or shrubs. Leaves mostly odd-pinnate with several leaflets. Stipules small, often quickly deciduous. Stipels present or not evident. Inflorescences racemose or spicate, otherwise various. Each flower with a single bract, these inconspicuous and deciduous to broad-clasping and persistent. Bracteoles present in some species groups. Corolla papilionaceous or appearing so. Standard often the shortest of the petals. Wings and keel arising from the hypanthium or laterally from the androecial tube (the latter in our species). Stamens apparently monadelphous, 9—10. Legume usually included within the calyx, with a thin pericarp, indehiscent.

Chromosome number. x = 7; counts on a limited number of species only (Darlington and Wylie, 1955; Turner 1956, 1960).

As herein delimited, Dalea is a polymorphic aggregate of considerable size, possibly 150 species. It is typically of the American cordillera and adjacent, mostly arid provinces, the United States to Chile.

The several interpretations of Dalea have been previously reviewed (Isely, 1958). On the basis of present information, I cannot agree with Shinnors' (1949) merger of Dalea and Petalostemon. This same position
has more recently been taken by Turner (1960). However, the interrelationships between Dalea and Petalostemon, with particular reference to interpretation of floral parts, deserves a careful morphological study.

Key to Species

1. Calyx teeth setaceous, exceeding tube, conspicuously plumose.

2. Leaves palmately trifoliolate.  
   2. Leaves with 5 or more leaflets.

3. Leaflets 5; petals yellow; plants not tall and branched.

   4. Plants erect; stems simple; spikes terminal, 2—5 cm long and 2 cm thick.  
   4. Plants decumbent, low; stems usually branching; spikes terminal or intercalary on a sympodial axis, considerably smaller than above.

   3. Leaflets 5—9; petals whitish; plants tall and branched.

1. Calyx teeth lanceolate, shorter than tube.

5. Flowers red-purple; leaves hoary with 6—7 pairs of leaflets; plants decumbent, perennial.

5. Flowers whitish; leaves glabrous with 12—15 pairs of leaflets; plants erect, annual.

Dalea aurea Pursh (Plate III. Map 2)

Stems clustered, erect or ascending from a woody taproot, appressed-hairy, usually simple. Stipules small. Leaves mostly with 5 leaflets, uppermost reduced. Leaflets obovate-elliptic to oblong, variable in width, loosely villous and remotely glandular below, villous to glabrate above. Peduncles terminating main stems, less frequently lateral branches, frequently well exserted but bearing reduced leaves. Spike hairy, ovoid in early flower, becoming cylindrical, usually 1.4—1.8 cm thick (appearing broader when flowers are expanded). Bracts ovate to spatulate, 3—4 mm long, short apiculate, closely villous on back. Expanded flowers 9—11 mm long. Calyx 6—7 mm, densely villous, the pilose, subulate teeth exceeding the body. Corolla yellow.


Phenology. Late June to early August. Greatest concentration of flowering usually in the last half of July.

Chromosome number. 2n = 14 (Turner, 1956).
Map 2. *Dalea aurea*

Nomenclature:

*Dalea aurea* Nutt. ex Pursh Fl. Amer. Sept. 740. 1814. (1, 2)

*Dalea aurea* Nutt. Fraser Cat. nom. nud. 1813.


Pursh (op. cit.) cited the Fraser catalogue as the basis of his *Dalea aurea*. The question of authorship (of the catalogue) is briefly reviewed in the present treatment under *Dalea enneandra*.

*Dalea enneandra* Nutt. (Plate IV. Map 3)

Plant perennial from a somewhat orange root. Stems erect, tall, (1—2 m) divergently branched, glabrous. Stipules very small. Leaves pinnate, mostly with 5—9 leaflets, these narrowly oblong but quickly involute on drying and appearing narrower. Spikes terminal on branches, loose, the flowers well separated. Bracts suborbicular, 2 mm long and as wide, short-cuspidate, conspicuously glandular, scarious marginated, enrolled about and concealing flower in bud, persistent and strongly sub-tending calyx in flower and fruit. Calyx 6 mm long, the body nerves, glabrous; teeth equalling or exceeding body, often reddish, setaceous, strongly plumose, the hairs exerted from the enveloping bracts before anthesis as a conspicuous "brush." Corolla somewhat exceeding calyx but inconspicuous, white with a touch of yellow or pink. Pod included.

Distribution and habitat. North Dakota, Texas, Iowa. Short grass plains and hills, often in sand; restricted to loess bluffs in eastern extremity of range.
Map 3. Dalea enneandra

Phenology. June—August; flowering peak usually early July in Kansas, the latter portion of this month in the Dakotas.

Discussion. Seed set in this species usually appears quite poor.

Nomenclature:

Dalea enneandra Nutt. in Fraser Cat. 1813. (2)
Dalea laxiflora Pursh Fl. Am. Sept. 741. 1814. (1)

The names Dalea enneandra and D. laxiflora are both of current utilization. A choice is dependent upon the acceptance or rejection, in the nomenclatural sense, of the Fraser Catalogue. This subject has recently been a matter of debate (Shinners, 1949, 1955, 1956; Cronquist, Keck and McGuire, 1956; Cronquist, 1957; Grausstein, 1956), a fact which suggests that any position may be open to challenge.

The present writer's employment of the epithet enneandra Nutt. indicates acceptance of the Catalogue. There seems to be no alternative. The Rules (Lanjouw, 1956) specifically outlaw tradesmen's catalogues as a medium of effective publication only subsequent to January 1, 1953.

Authorship of the Catalogue has also been debated and several reasons for believing that Nuttall was or was not the author of the Catalogue have been advanced (authors cited above). I agree with Cronquist, Keck and McGuire (op. cit.) that authorship is a secondary issue and does not bear upon effective publication. However, it seems proper to regard Nuttall as the author. A reasonably definitive basis on which to establish such a
supposition is simply that he (Nuttall) claimed authorship in subsequent publications. For example, among the names of legumes treated in this manuscript he takes up Amorpha nana, A. canescens, and Psoralea incana, citing them "T. N. in Fras. Cat." (Nuttall, 1818).

**Dalea jamesii** (Torr.) T. and G. (Plate V. Map 13)

Stems clustered from a woody caudex, low, 0.3—2 dm long. Stipules acicular, becoming spiny, to 4 mm. Leaves palmately trifoliolate. Leaflets obovate, 1.5—2 times longer than broad, appressed-silky on both sides, scarcely glandular. Spikes terminal, nearly sessile, ovoid and dense in bud and flower, loosening in fruit. Bracts ca. 6 mm, narrowly ovate, acute or acuminate tipped, equalling calyces prior to anthesis. Calyx about 10 mm, closely villous, inconspicuously glandular, the acicular plumose teeth exceeding tube. Corolla yellow, turning dull reddish in age. Standard exceeding calyx but other petals shorter. Pod included, fimbriate villous, roughly obovoid but asymmetric; style semipersistent, cuneate, laterally or upwardly directed, abruptly bent.

**Distribution and habitat.** Colorado, Kansas, Mexico. Dry plains. Infrequent.

**Phenology.** June—July, Kansas and Colorado; earlier farther south.

**Nomenclature:**

Dalea jamesii (Torr.) T. and G. Fl. N. Amer. 1:308. 1838. (2)

**Dalea lanata** Spreng. (Plate III. Map 4)

Perennial, mat-forming prostrate plants. Stems from a taproot, clustered, much branched. Stipules inconspicuous. Leaves pinnately compound, often subsessile; leaflets 6—7 (9) pairs, broadly to narrowly elliptic, villous to lanate on both sides, strongly glandular beneath (glands large, umbonate). Spikes opposite leaves (the branching thus sympodial), in bud short-peduncled and conical, elongating in flower and fruit, becoming exserted, loose and somewhat sinuate, 4 mm wide, to 1 dm in length. Bracts and calyx both closely villous, sparsely glandular with large glands. Bracts with an ovate body, equalled or exceeded by the subulate tip. Calyx about 4 mm long, the lanceolate teeth shorter than the tube. Corolla red-purple, 5—6 mm. Fruit included, villous; asymmetrically obovate, the tip laterally directed.

**Distribution and habitat.** Southwestern Kansas to Mexico. Dry plains, sand.

**Phenology.** July or later in northern part of range.

**Chromosome number.** Turner (1956) reports n = 7.

**Nomenclature:**

Dalea lanata Spreng. Syst. Veg. 3:327. 1826. (2, 3)

(2, 3)

Sprengel's description of this plant is not sufficiently complete to be definitive. However, Torrey and Gray (1838-40, p. 690), in equating their D. lanuginosa (op. cit. pp. 307-308) with D. lanata, apparently had access to Sprengel material. Their description of D. lanuginosa is unequivocal.
Dalea leporina (Ait.) Bullock (Plate IV. Map 4)

Plants annual, erect, branched, glabrous except for inflorescence. Stems and leaves conspicuously punctate. Stipules small. Leaves pinately compound, mostly with 10—15 or more pairs of small elliptic leaflets. Spikes dense, pubescent, terminating leafy stems. Bracts soon lost, loosely pubescent to glabrate, obovate with an abrupt acumen; the body about 1.5 mm long; the tip of equal length. Calyx 3—4 mm long, closely pubescent, the subequal teeth somewhat shorter than the tube. Flowers 6—7 mm, whitish, tinged with blue or pink or almost entirely blue-purple. Pod included within calyx.

Distribution and habitat. Minnesota, Arizona, Mexico, Central America; also reported from South America—introduced? Sporadically introduced in the eastern states. Usually in sandy or alluvial soil in the north-central states, frequently along streams; also in disturbed areas. Locally common.

Phenology. Late flowering, August—September in our range.

Variability and specific delimitation. Dalea leporina seems to be a geographically extensive but loosely unified taxon. Since the tropical representatives differ from their north-temperature congener, many—perhaps the majority—of workers have considered the complex to include two species: Dalea alopecuroides Willd. of the United States, south to Arizona and New Mexico and Dalea leporina from the southwestern United States to Central America.

The characters employed to distinguish the northern and southern elements have included flower color—Dalea leporina in the limited sense being purplish, D. alopecuroides possessing whitish petals tinged with blue; additional characters are afforded by the color of the apex of the stamen column, the pubescence and width of the scarious margin of the bracts. The Central American plants and those from the northern United States appear reasonably distinct on the basis of the above differential characters. But the two forms merge in the central portion of their range—Arizona and northern Mexico. Many specimens are difficult to associate definitively with either "typical" type; the degree to which white flowers are tinged with blue varies widely; the bract and stamen characters do not necessarily correlate; bract pubescence in particular is widely variable. Attempts to find further features possibly having critical value have proved futile. Irrespective of the evolutionary or historical basis of the present situation (conceivably introgression between two once reasonably distinct units) we would seem currently to be dealing with a single, albeit bifurcate unit.

In line with the above reasoning, it is unfortunately necessary to dispense with the name Dalea alopecuroides for the north-central states inhabitants and take up the older D. leporina (see nomenclature). If subspecific designation is desired, the northern element is D. leporina var. alba (Michx.) Harrington.

Chromosome number. 2n = 14 (Atchison, 1949).

Discussion. Dalea leporina is the only annual among the north-central states Psoraleae; the habit is easily determinable from the slender taproot of specimens in contrast with the variously thickened and woody, or rhizomatous caudices of its relatives.

Perhaps the gross size and vigor of annuals is more subject to the vagaries of the environment than that of related perennials. This seems
Map 4. *Dalea leporina* (circles); *Dalea lanata* (squares).

to be true for *Dalea leporina*. Depending upon the habitat (and possibly time of seed germination), flowering specimens may range from a few inches in height to 3–5 feet.

This plant is grown to a limited extent for soil improvement and seed is commercially available.

Nomenclature:

*Dalea leporina* (Ait.) Bullock *Kew. Bull.* 1939:196. 1939 (June 7);


*Dalea alopecuroides* Willd. *Sp. Pl.* 3:1336. 1802. (1, 2)


*Parosela alopecuroides* (Willd.) Rydb. *N. Amer. Fl.* 24:78. 1920. (1, 3)

Aiton's description of *P soralea leporina* (op cit.) is too limited to be definitive. I have followed the traditional concept of the identity of his material.

*Dalea nana* Torr. (*Plate V. Map 1*)

Stems numerous from a woody caudex, spreading, ascending at tips or sometimes nearly erect, usually branched. Stipules small, acicular. Leaves 5-foliolate, the leaflets broadly elliptic to narrowly oblong, densely to sparingly villous, especially below. Spikes ovoid to short-cylindric, terminal or pseudo-axillary (branching sympodial). Bracts
ovate, ca. 4 mm long, less than twice as long as wide, short-apiculate, shorter than the expanded calyces, dorsally villous. Calyces 6 mm long, the setaceous, plumose teeth exceeding the tube. Petals exceeding the calyx teeth, lemon yellow, turning pink in age.

Distribution and habitat. Southwestern Kansas, Arizona, Texas, Mexico. Dry open soil, sand hills.

Phenology. July (Kansas and Colorado); earlier farther south.

Discussion. Dalea nana barely extends into the north-central states (southwestern Kansas) wherein its determination presents little difficulty. To the southwest, however, Dalea nana is less emendable to interpretation. The delimitation of the yellow flowered daleas, in general, seems to await a satisfactory elucidation.

Nomenclature:


Petalostemon Michx.

(Kuhnistera Lam.; Dalea in part, sensu Shinners)

Herbaceous perennials, rarely annual, usually arising from a woody long-lived taproot surmounted by a shoot-producing caudex. Stems usually numerous, often unbranched below, erect or ascending in most species. Stipules setaceous, inconspicuous, deciduous. Principal leaves odd-pinnate with 5—7 (9) leaflets, more in a few species. Upper leaves frequently reduced. Leaflets ovate-elliptic to linear, often involute.

Flowers one per bract, closely compacted in peduncled spikes which terminate main stem and upper branches. Spikes ovoid, conical or short-cylindric at anthesis, frequently elongating in fruit. Bracts deciduous or semipersistent, roughly lanceolate, often with a conduplicate or stalk-like base, with a long or short acumen, frequently conspicuously pubescent. Filiform bracteoles present in some species. Calyx slightly asymmetric, the teeth shorter than tube. "Petals" 5, nonpapilionaceous; 4 of them, elliptic to strap-shaped, arising from apex of stamen tube and alternating with stamens, often short-clawed. Vexillum long-clawed, included or obliquely exserted, indehiscent, sally 1-seeded.

Petalostemon is an American group of approximately 35 species with the greatest number of kinds in Texas. The delimitation of the genus and interpretation of the androecial "corolla" is detailed elsewhere (Isely, 1958). A 2n chromosome number of 14 has been reported for 7 species of the genus (Turner, 1956; Ledingham, 1957).

A total of 8 species of Petalostemon are herein recognized for the north-central states. Their prevalence in general increases from north to south and east to west. They frequently receive the generic common name of prairie clover.

Petalostemon Michx. (1803) is conserved over the earlier Kuhnistera Lam. (1789). The spelling and gender herein adapted are those employed in the Nomina Generica Conservanda.
Key to Species

1. Principal leaves with 11 or more leaflets.

2. Plants villous; plains species occurring primarily west of the Mississippi. \( P. \) *villosum*

2. Plants glabrous; endemic of rare occurrence in Illinois and Tennessee. \( P. \) *foliosum*

1. Principal leaves with 5—7 (9) leaflets.

3. Flowers white or yellowish-white.¹

4. Calyx villous; spikes frequently very long, to 1 dm or more. \( P. \) *compactum*

4. Calyx body glabrous or finely puberulous, teeth usually puberulous; spikes less than 1 dm in length.

5. Spikes globose to ovoid, not exceeding 1.5 cm in length; bracts 2.0—2.5 (3.0) mm long, shorter than calyces, scarcely discernible even in bud. \( P. \) *multiflorum*

5. Spikes becoming cylindric in fruit, usually exceeding 1.5 cm; bracts (2.5) 2.8—4 mm long, approximating or exceeding calyces, at least in bud.

6. Spikes loosening in fruit so that calyces are not immediately contiguous; stem surface of rachis visible; calyx usually finely puberulous, its nerves drawn out into flanges or narrow wings. \( P. \) *occidentale*

6. Spikes not loosening in fruit; surface of rachis entirely occupied by the contiguous flowers; calyx glabrous (except for teeth), the nerves usually appearing as rounded ridges, less frequently somewhat flange-like. \( P. \) *candidum*

3. Flowers pink to purple.

7. Bracts broadly ovate, without a folded stalk-like portion below the body, pubescent over most of surface; spikes loosely cylindric, usually somewhat flexuous; rachis scars of flowers not immediately contiguous. \( P. \) *tenuifolium*

¹A rare form of \( P. \) *purpureum* possesses white flowers. It has filiform-involute leaflets. The leaflets of the white-flowered species are broader.
7. Bracts short-oblong, the lower portion folded, narrower than the body and somewhat stalk-like; pubescence usually in a distinct band in middle of bract, the distal and proximal portions glabrate (in southern portion of range, a line of pubescence may extend down stalk); spikes ovoid to densely cylindric; flower scars contiguous. \textit{P. purpureum}

\textit{Petalostemon candidum} Michx. \textit{(Plate VI. Map 5)}

Plants erect, glabrous, with clustered stems, mostly branched above middle. Principal leaves 7-foliolate; upper portion of stem frequently with 5- and 3-foliolate blades. Leaflets of lower leaves elliptic, up to 6 mm in width and 2 (3) cm long; upper leaves smaller, the leaflets becoming proportionately narrower than lower ones.

Inflorescence of one to several well-peduncled (up to 10 cm) spikes; peduncle often bearing 2—3 reduced unifoliolate leaves or bract-like scales. Spikes ovoid to conic when young, becoming stiffly cylindric in fruit, 2—5 cm long, 1.2—1.4 cm wide when flowers are expanded, about 1 cm wide in fruit.

Flowers white, closely crowded, completely obscuring inflorescence axis, the surface of which after abscession of fruits is entirely occupied by attachment scars.

Bracts glabrous, strongly exserted and conspicuous in bud, the lowermost merging with reduced leaves on the peduncle, 4—5 mm long, and exceeding mature calyces; the upper 2.8—3.5 mm and equaling or slightly shorter than calyces; body obovate; acumen lanceolate, similar in texture to body, various in length. On abscession, the bracts separate slightly above the surface of rachis leaving a distinct "heel." A pair of bristle-like secondary bracts subtend each flower.

Calyx slightly asymmetric, ca. 3 mm in length, glabrous except for the finely pubescent, darkened teeth; body appearing somewhat bony; ribs angular or flange-like, or evident only as rounded dark lines; large sessile glands usually evident at base of sinuses, between teeth.

Distribution and habitat. Southern Wisconsin, Manitoba, Texas, Alabama. In the north-central states, absent primarily from the northern coniferous forest provinces and from the western portion of the plains states. In this latter area, it is replaced by \textit{P. occidentale} (Heller) Fernald. Prairies and plains; in open woodland, prairie openings, glades, along roadsides at margins of range (eastern and southern particularly). Frequently conspicuous in prairie remnants in Iowa and adjacent portions of the surrounding states.

Phenology. Flowering peak: June (Kansas, Missouri); first half of July (Iowa, Indiana, Illinois); latter July (Minnesota, the Dakotas).

Variability and delimitation. For a wide ranging species, \textit{P. candidum} is consistent morphologically. Principal evident variation concerns the foliage, size and shape of the leaflets and the extent to which upper leaflets become narrower than lower ones.

Botanists have not been of one mind as to the status of this species and \textit{P. occidentale}. The characteristics of the complex are reviewed in detail in another publication (Isely and Welsh, 1960). In summary: two species are involved of which \textit{P. candidum} is the eastern representative.
Map 5. *Petalostemon candidum* (circles); *Petalostemon compactum* (squares).

and *P. occidentale* the western. There seems to be occasional introgression where the two species come together but for the most part they are distinct.

Usually *P. candidum* can be recognized at a glance by its broader foliage, and its bulkier, stiffly straight inflorescences. The habit is ordinarily erect; *P. occidentale* is frequently semiprostrate or spreading. The following is a summary of basic, differential characters:

<table>
<thead>
<tr>
<th></th>
<th><em>P. candidum</em></th>
<th><em>P. occidentale</em></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spike:</strong></td>
<td>densely flowered; attachment scars of flowers completely occupying surface of rachis.</td>
<td>More loosely flowered, especially evident in fruit; attachment scars of flowers separated by intervening areas of stem surface.</td>
</tr>
<tr>
<td><strong>Calyx:</strong></td>
<td>Surface glabrous; ribs rounded to flange-like.</td>
<td>Surface usually finely puberulent; ribs flange- to wing-like.</td>
</tr>
</tbody>
</table>

Chromosome number. 2n = 14 (Ledingham, 1957; Turner, 1960).

Nomenclature:
Many authors cite this name *P. candidum* (Willd.) Michx. However, since Michaux did not cite Willdenow (the contrary is in fact the case), his epithet would seem to be most properly considered a new name rather than a combination.

**Petalostemon compactum** (Spreng.) Swezey (Plate VII. Map 5)

Plants from a woody, frequently orange taproot. Stems and herbage essentially glabrous except for inflorescence. Leaves 7-9 foliolar, strongly glandular. Leaflets elliptic-oblong, 2-6 mm wide. Spikes long-pedunculate, terminating leafy branches, villous, cylindric, ca. 1 cm wide, often becoming very long, up to 15 cm in fruit, frequently sinuate or recurved at tip. Flowers yellowish-white. Bracts linear lanceolate, 4-5 mm long and slightly exceeding calyx; apex darkened; dorsal surface with stiff, outwardly directed or ascending hairs. Calyx 3-4 mm in length, appearing longer because of an indument of tawny, stiff pubescence which completely obscures the surface.

Distribution and habitat. South Dakota and Wyoming to Texas. An uncommon western plains species, sand hills and knolls.

Phenology. Latter July and August.

Nomenclature:

*Petalostemon compactum* (Spreng.) Swezey Nebr. Fl. Pl. 6. 1891.

(4)

*Dalea compacta* Spreng. Syst. Veg. 3:327. 1826. (4, 2)


(4, 2)

The employment of the binomial *Petalostemon compactum* (Spreng.) Swezey for this species is not beyond criticism. *Dalea compacta* Spreng. cannot be identified by description and the original material does not seem to be in existence. The author corresponded with several European herbaria in an attempt to locate such a specimen or specimens. Apparently the Sprengel collections were broken up in the 1860's. Several herbaria now have some sheets but the preponderance in Berlin-Dahlem were destroyed during the war.

On the other hand, *Petalostemon macrostachyum* Torr., published two years subsequent to Sprengel's name is clearly identifiable by description. It was employed by 19th century botanists for this species until Kuntze's and Swezey's more or less simultaneous combinations relegated it to synonymy. Since then the epithet *compactum* has been taken up by most botanists. Probably it is best to continue its utilization.

From the standpoint of a positive approach, why did Kuntze and Swezey believe that *Dalea compacta* Spreng. was the same as *Petalostemon macrostachyum*? Neither author offers an explanation. Probably Swezey was following Watson (1878) who tabulated *Dalea compacta* Spreng. as a synonym of *P. macrostachyum* Torr., and Kuntze may have done likewise. On the other hand, Kuntze may have examined Sprengel material then in existence. And the basis of Watson's earlier decision? It would appear probable that he had some information concerning the Sprengel specimens to reach a decision, since the description could be of little help.
Petalostemon foliosum Gray (Plate VIII. Map 9)

Plants ascending with spreading branches, glabrous. Stem somewhat glaucous. Leaves with 10 or more pairs of leaflets, these elliptic. Spikes numerous, short-stalked, becoming cylindrical and several centimeters long. Flowers apparently pinkish to rose. Bracts lanceolate, 4.5—5.0 mm long, well exceeding calyx in bud but quickly deciduous. Calyx ca. 4 mm in length, distinctly ribbed, glabrous except teeth, pubescent on inner surface and ciliate.

Distribution and habitat. Northern Illinois and vicinity of Nashville, Tennessee. The species has not been reported from the intervening state of Indiana (Deam, 1940), and there are no specimens in the Indiana University Herbarium.

Phenology. Summer.

Discussion. Petalostemon foliosum is very possibly now extinct. All specimens seen were collected in the last century.

Nomenclature:

(1, 2)

Petalostemon multiflorum Nutt. (Plate IX. Map 6)

Stems clustered, much branched above, essentially glabrous. Principal leaves about 7-foliolate, the upper reduced; blades smooth, often conspicuously glandular. Leaflets of lower leaves oblong-elliptic to obovate; those of the crowded upper ones narrowly elliptic to linear, 1.5—2 mm wide, sometimes involute.

Inflorescence bushy-branched, broad. Spikes numerous, shortly peduncled above reduced leaves, usually without accessory bracts, globose to ovoid, 1.0—1.3 cm in length and not lengthening in fruit. Flowers white, contiguous on rachis. Bracts broad and short, 2.0—2.5 (3.0) mm, with a short acuminate tip, shorter than calyces and scarcely discernible even in bud. Calyces 3.0—3.5 mm long; tube glabrous and rather sharply ribbed; teeth darker colored and with sparse, fine pubescence.

Distribution and habitat. Western Iowa to Texas, occasional (introduced?) farther east. Rocky prairies.

Phenology. June (southern portion of range) to July-August (northern).

Discussion. P. multiflorum is related to the P. occidentale—candidum complex. It is especially characterized by the short spikes which do not elongate in fruit and flowers which clearly exceed the broad bracts. The calyces are similar to those of P. occidentale but ordinarily lack the fine pubescence on the body.

Nomenclature:

Petalostemon multiflorum Nutt. Jour. Phil. Acad. 7:92. 1834. (2)

Petalostemon occidentale (Heller) Fernald (Plate VII. Map 7)

Stems clustered, prostrate, ascending to erect. Stems and foliage glabrous. Leaves various, main blades about 7-foliolate, with elliptic leaflets. Middle and upper leaves often crowded, appearing reduced with smaller, narrowly oblong or linear leaflets (1—2 mm wide).

Peduncles shortly exerted, mostly less than 5 cm above last trifoliate leaf and with 1—2 accessory bracts below inflorescence. Spikes ovoid, short oblong in flower, lengthening and loosening in fruit, becoming
Map 6. *Amorpha nana* (squares); *Petalostemon multiflorum* (circles); *Petalostemon tenuifolium* (triangles).

Map 7. *Petalostemon occidentale*
somewhat flexuous; the calyces not immediately contiguous, rachis surface thus discernible between. Bracts lanceolate, glabrous, variable in length, (2.5) 2.8—3.5 mm, the lower exceeding flowers, the upper approximating flowers, mostly deciduous at anthesis, and not as conspicuous as in P. candidum. Bracts dehiscing flush with the surface of rachis or leaving a slight heel. Acicular secondary bracts also present.

Flowers white. Calyx usually finely puberulous over surface, the darkened teeth more closely hairy with stiffer hairs; ribs distinct, raised and somewhat wing-like.

Distribution and habitat. Alberta, Idaho, Mexico, southwestern Wisconsin (introduction?), western Iowa. Frequently abundant. A species primarily of the short grass plains with sporadic incursions eastward, as along Missouri River bluffs, possibly also of recent introduction beyond original limits. Plains, rocky hills, bluffs, buttes.

Phenology. June and July. Flowering peak usually first half of July in north-central states.

Variability and specific delimitation. Most conspicuous variability is exhibited by the leaves. Races from the northwestern portion of the range (e.g. Montana, Idaho) tend to have small leaves but relatively broad leaflets (e.g. 1 cm long, 4 mm wide). The majority of the leaves of the southwestern types (Texas, New Mexico) possess narrow, even filiform-appearing leaflets. Forms of similar morphological appearance occur along the Missouri River loess bluffs in western Iowa. A wide variety of types is to be found in Nebraska and Colorado.

This, the western counterpart of P. candidum, has been extensively confused with the latter species. The two are usually amply distinct; only occasionally in areas in which species come together does one find material apparently intermediate in nature. Difficulties in distinguishing the two have arisen primarily from descriptive emphasis upon poorly chosen (i.e. variable) characters (Isely and Welsh, 1960).

Specimens of P. occidentale possessing only late-summer depauperate spikes are not infrequently determined as P. multiflorum. Even though such spikes do not elongate and remain short and dense (thus simulating P. multiflorum) some evidence of pubescence can usually be found on the calyx tubes; the bracts, if still present, equal or exceed the flowers (shorter than the flowers in multiflorum), and there are usually accessory bracts below the inflorescence.

Nomenclature:


(2, 3)

Petalostemon gracile oligophyllum Torr. in Emory, Notes Mt.
Rec. Ft. Leavenworth, Missouri. 139. 1848. (2?, 3)

1895. (2)

1:237. 1900. (3)

Petalostemon candidum var. oligophyllum (Torr.) Herman Jour.
Wash. Acad. Sci. 38:237. 1948. (3)

The oldest epithet presumably referable to this taxon is oligophyllum Torr. However, transfer of oligophyllum Torr. to specific rank (1900) was superseded by Kuhnistera occidentalis Heller (1895).
Fernald (loc. cit.) cites *P. occidentale* (Gray) comb. nov. The name *occidentale* was used by Gray on Pringle 1216 but never published. Effective publication was by Heller, hence Gray ex Heller. If a double citation is to be reduced to a single name, the Rules (Lanjouw, 1956; Article 46A) recommend "the name of the publishing author, being more important should be retained."

**Petalostemon purpureum** (Vent.) Rydb. (Plate VIII. Map 8)

Plants glabrous or variously villous. Leaflets (3) 5, oblong to filiform, mostly folded or rolled. Spikes usually numerous, short-peduncled, ovoid to conical in bud, becoming short- to long-cylindric in fruit, 0.8–1.0 (1.3) cm wide. Flowers bright violet to pink.

Bracts oblong, about 4 mm long, approximating flowering calyces but exceeding them in bud, the exserted, darkened tips then prominent; lower portion folded, somewhat narrower than the short body and appearing stalk-like; pubescence normally restricted to a central band but sometimes extending downwards on stalk. Calyx 3.5–4.0 mm long, closely villous-pubescent; this pubescence, especially that at base of calyx usually having a tawny appearance.

Map 8. **Petalostemon purpureum**

Distribution and habitat. From Alberta to southern Michigan, New Mexico, northern Texas to Alabama, occasionally introduced farther east. In the north-central states, a typical plant of the plains and prairies;
farther west, open range land hills, ridges, buttes, etc. in dry or moist soils of a variety of types; once widely abundant, still conspicuous in remnant areas. Distribution more local and discontinuous in adjoining provinces, mostly prairie openings; sometimes open woodland.

Phenology. Flowering June–August; Missouri and Kansas, latter June–July; North Dakota, Minnesota, latter July, August.

Variability. For an abundant and wide ranging species, *P. purpureum* is reasonably consistent morphologically except to the southwest. The majority of populations consist largely of essentially glabrous individuals, but villous plants or populations may be encountered apparently at random throughout the range. The degree of pubescence of such plants is various. They have frequently been termed variety or forma pubescens under several authorships. North and west (primarily Colorado, Wyoming and Montana) the possible presence of a hairy geographical variety is evidenced by the frequent correlation of foliage and stem pubescence with greater villosity and thickness of the spikes and frequently broader and wider leaflets. However, this form (*Petalostemon molle* Rydb. or *P. purpureum molle* (Rydb.) Nels.) does not replace the "typical" species but appears to occur in conjunction with it; furthermore, the characters involved are not invariably associated; e.g. forms with smooth stems and leaves may have the broader, more densely hairy spikes characteristic of mollis.

In sand, *P. purpureum* may assume a low or prostrate habit, forma arenarium Gates. Forma albiflorum Horr. and McGregor has white flowers.

In Texas, *P. purpureum* is largely replaced by related kinds (*P. pulcherrimum* Heller, *P. stanfieldii* Small, *P. tenue* Gray). In the intermediate areas, southern Missouri, Arkansas and Oklahoma, there is observational evidence of genetic infiltration between these species and *P. purpureum*. For example, although *P. pulcherrimum* does not appear to occur in Missouri, its genetic influence seems to extend to the *P. purpureum* populations in the southern part of that state, and has served as the basis of reports of *P. pulcherrimum* from Missouri.

Chromosome number. 2n = 14 (Ledingham, 1957).

Nomenclature:


*Dalea purpurea* Vent. Descr. Pl. Cells. 40. 1801. (2, 3)

*P. violaceum* Michx. Fl. Bor. Amer. 2:50. 1803. (2, 3)


The name *P. violaceum* Michx. will be found on most 19th century specimens of this species.

*Petalostemon tenuifolium* Gray (Plate IX. Map 6)

Plants low, mostly branched. Leaves and stem glabrous or occasionally hirsute. Leaves largely 5-foliate with strongly glandular, involute or folded leaves. Spikes short-exserted, very villous, short-oblong in flower, rapidly becoming slender, loosely cylindric, often curved or bent. Flowers pink, not immediately contiguous.

Bracts 3.0–3.5 mm long, evident before anthesis but soon deciduous; body rather broad, scarcely narrowed to base, villous over entire dorsal
surface; acumen relatively short, the dark surface usually showing through thinning pubescence.

Calyx 3.5–4.5 mm at anthesis, obscured by a dense indument of long (up to 0.8 mm), straw-colored pubescence. Calyx teeth well-developed, 1 mm or more in length.

Distribution and habitat. Eastern Colorado and southwestern Kansas to Texas.

Phenology. July, August.

Discussion. This distinctive member of the purple-flowered complex is easily recognized by its loosely-flowered inflorescence, long pubescent calyces, and completely pubescent, broad bracts. The confusion which appears to exist, both in literature and on herbarium sheets, between this and related species, seems unwarranted.

Nomenclature:

**Petalostemon tenuifolium** Gray Proc. Amer. Acad. 11:73. 1876.

(P1, 2)

**Petalostemon villosum** Nutt. (Plate VI. Map 9)

Stems radiating or ascending, usually clustered and unbranched. Herbaceous densely gray-villous to (less frequently) sparsely pubescent. Leaves short-petioled with about 13 (9–15) elliptic leaflets. Spikes short- or long-cylindric, to 1 dm in length, often somewhat sinuous, densely villous. Flowers pale pinkish-lavender. Bracts ovate, with a lanceolate-attenuate tip, closely hairy, 4.0–4.5 mm long, exceeding buds, deciduous before anthesis. Calyx 3.0–3.5 mm, distinctly ribbed but surface largely obscured by dense pubescence. Anthers conspicuous, orange.

Map 9. Petalostemon villosum (circles); Petalostemon foliosum (squares).
Distribution and habitat. Western Wisconsin, Manitoba, Texas, Missouri, usually in sand.

Phenology. Flowering July, Kansas; August, Minnesota, Wisconsin.

Variability. Populations and individuals differ chiefly in degree of pubescence, and shape and number of leaflets. Plants from Texas and Oklahoma are frequently less villous than the more northern representatives.

Chromosome number. $2n = 14$ (Ledingham, 1957).

Nomenclature:

Petalostemon villosum Nutt. Gen. 85. 1819. (2)

Psoralea L.
(including Orbexilum Raf., Psoralidium Rydb., Pediomelum Rydb.)

Plants herbaceous perennials (in our range) from varied types of rootstocks. Stems usually erect, much branched to simple. Leaves pinnately or palmately foliolate, usually conspicuously glandular. Stipules evident. Inflorescences racemose or spicate, congested or diffuse, often strongly pedunculate. Flowers 2—3 per bract. Calyx two-lipped (the lower tooth usually longest) or less frequently nearly regular, often enlarging in fruit. Corolla papilionaceous, not associated with androecium, lavender to purplish, or less frequently nearly white. Wings often partially connivent or articulated. Stamens typically 10 and diadelphous. Legume 1-seeded, enclosed within or exserted beyond persistent calyx, indehiscent or fragmenting irregularly at maturity. Pericarp thick- or thin-walled, usually glandular, smooth or variously ornamented.

Psoralea is a widely distributed genus with a number of species both in Africa and North America. The circumscription, as herein defined, has previously been discussed (Isely, 1958) and will not be reiterated.

Most species for which chromosome number determinations have been made possess a basic $x = 11$; $x = 10$ has, however, also been reported.

Key to Species

1. Leaves pinnately foliolate.

2. Leaves 3 or more times as long as wide; pods as broad as long, conspicuously cross-ridged. **P. psoralioides**

2. Leaves less than 3 times as long as wide; pods longer then broad, tuberculate. **P. onobrychis**

1. Leaves palmately foliolate.

3. Calyx 2—3 mm long; fruit exposed.

4. Fruit longer than broad; flowers lavender to violet; glandular dots on leaves not variable in size.
5. Leaflets linear, about 2 mm wide; pedicels slender, about 8 mm in length.  
   *P. linearifolia*

5. Leaflets obovate to oblong, 3–8 mm broad; pedicels 2–4 mm long.  
   *P. tenuifolia*

4. Fruit subglobose; flowers whitish except for purple tip on keel; glandular dots on leaves various in size.  
   *P. lanceolata*

3. Calyx (at least lower tooth) 5 mm or more in length; fruit partially or completely hidden by enlarging and persistent calyx.

6. Flowers at anthesis in well-separated whorls; calyx about 6–7 mm long.

7. Lower calyx tooth subulate; equaling or exceeding corolla; plant usually conspicuously silvery, but upper leaf surfaces often greenish.  
   *P. argophylla*

7. Lower calyx tooth broadly lanceolate, shorter than corolla; plant gray-strigose to greenish.  
   *P. digitata*

6. Flowers at anthesis crowded in dense spikes; calyx usually about 10 mm long.

8. Pubescence spreading.  
   *P. esculenta*

8. Pubescence appressed.

   *P. hypogaea*

   *P. cuspidata*

*Psoralea argophylla* Pursh (Plate XIV. Map 10)  
Plant perennial from a slender or thick, black rootstock. Stems single, erect, divaricately branched, silvery-sericeous. First 1 to 2 leaves represented by ensheathing stipules, subsequent ones 4–5 foliolate on main stem, usually 3-foliolate on branches. Leaflets variously shaped, usually obovate to elliptic, typically silvery-silky below and somewhat less pubescent above, ranging to greenish, especially above. Stipules of blade-bearing leaves subulate, those of lower ones to 1 cm in length, the upper progressively shorter.  
Spikes axillary, becoming long-peduncled, each comprising 3–5 ultimately well separated whorls of about three flowers each. Bracts ovate, pointed, semipersistent, approximating buds. Lower calyx lobe 7–8 (5–10) mm long, exceeding the others, approximating or longer than standard. Corolla blue-violet, fading to straw-color. Fruit appressed-villous, 8–9 mm long, including the broad, flat beak; body largely enclosed by the adherent calyx.
PSORALEAE

Map 10. *Psoralea argophylla*

Distribution and habitat. Saskatchewan, New Mexico, Missouri, Illinois. Frequently conspicuous in prairie remnants, native meadows, on rocky slopes, outcrops, bluffs; in woodland in adjoining provinces.

Phenology. Blooming period extending through much of summer; initiating latter June, Kansas and Missouri; July and early August, Minnesota and North Dakota.

Variability. *Psoralea argophylla* is, by merit of its silvery appearance and distinctive inflorescence, a well-marked species. However, it possesses considerable morphological variability. There is a wide range in "robustness"; husky, heavy plants contrast strongly with small tenuous ones. No doubt this is, in large part, a vigor response to growth sites, but the presence of varied ecotypes is suggested. The density of pubescence is diverse. Leaflet shape ranges from broadly oval or narrowly elliptic; the leaflets are usually rounded or pointed at the apex but some are notched. The degree of development of the lower calyx lobe, frequently employed as a key character for this species, is highly variable.

*Psoralea collina* Rydb., described from Nebraska seems to be *P. argophylla* with leaves thinly pubescent on upper surface and the lower calyx lobe little elongated.

Chromosome number. 2n = 22 (Ledingham, 1957).

Discussion. This species is one of the more common prairie plants still persistent in remnants of natural vegetation throughout its range. Its silvery coloration renders it conspicuous and easily discerned. The names scurf-pea and silver leaf are employed in some treatments, but no common name appears well established.
Psoralea cuspidata Pursh (Plate X. Map 11)

Stems from a slenderly fusiform root, strigose, erect to reclining, with widely spreading branches. Stipules broadly or narrowly lanceolate, to 1 cm or more. Leaves palmately 5-foliolate; leaflets obovate to elliptic, often narrowly so, closely strigose below, glabrate and glandular above.

Spikes axillary, on stout peduncles, in bud and anthesis rather short and of closely compacted flowers, becoming looser in fruit. Bracts ovate-acuminate, bristle-tipped, ca. 1 cm. Flowering calyx about 8 mm long, strigose and glandular; tube slender, subequal to the conspicuous teeth of which the ventral is longest. Corolla appearing blue-lavender; standard and wings about 1.5 cm long; keel somewhat shorter, purple tipped, proximally whitish. Fruiting calyces considerably enlarging, conspicuously glandular, enclosing fruit. Pod 7—8 mm long, strigose at top, with a short flat beak.

Map 11. Psoralea cuspidata (squares); Psoralea psoralioides (circles).
Distribution and habitat. Montana, South Dakota to central Texas. Undisturbed prairies, low meadows, sandy slopes, limestone hills, bluffs, locally common, sometimes regarded as a weed in range land.

Phenology. Flowering June (Kansas) to July (South Dakota).

Variability. In our range at least, *Psoralea cuspidata* appears to be more consistent morphologically than the preponderance of *Psoralea* kinds. The southwestern representatives are more varied; e.g. in Texas, Tharp and Barkley (1945) have interpreted *Psoralea cuspidata* as three species and Turner (1960) refers to geographically distinctive populations. While *Psoralea cuspidata* is probably to be grouped with the *Psoralea esculenta* alliance, it does not seem to be intimately related to any of our other species.

Chromosome number. $2n = 22$ (Turner, 1960).

Nomenclature:
- *Psoralea cuspidata* Pursh Fl. Amer. Sept. 2:741. 1814. (1, 2)
- *Pediomelum caudatum* Rydb. N. Amer. Fl. 24:19-20. 1919. (1, 2)
- *Psoralea caudata* (Rydb.) Cory Rhodora 38:406. 1936. (1, 2)
- *Pediomelum parksii* Tharp and Barkley Madrono 8:49. 1945. (1, 2)

The above synonymy is based on a circumscription of *Psoralea cuspidata* inclusive of the later named Texas variants.

*Psoralea digitata* Nutt. in T. and G. (Plate XI. Map 12)

Stems erect from slender rootstocks, widely branched, up to 1 m in height. Stipules oblong, appressed-canescent. Leaves palmately 5- or the uppermost 3-foliolate. Leaflets ob lanceolate, oblong or linear, 5—10 times as long as wide, the lower considerably broader than the upper. Upper surface usually glabrate and glandular; lower strigose. Spikes long peduncled and interrupted; whorls well separated, of 3 or more subsessile flowers. Bracts obovate to spatulate. Flowering calyx appressed-villous, about 6 mm long, the lower tooth somewhat the longest. Corolla bluish, 7—8 (6—10) mm long. Fruiting calyx enlarged, enclosing the fruit. Legume thin-walled, strigose, with a short flattened, straight beak.

Distribution and habitat. South Dakota to central Texas; high plains (north) to open woodlands in Texas.

Phenology. June to early July.

Variability. Some of the southwestern material, especially from Texas, possesses strikingly narrow leaflets. This form appears to be Shinners' var. *parvifolia* (1951).

Chromosome number. $n = 11$ (Turner, 1956).

Discussion. Although of relatively wide distribution in the southern great plains, this species seems to be of sporadic or local occurrence. It is much less frequently seen than, for example, *P. tenuiflora* and *P. lanceolata*.

*Psoralea digitata* and *argophylla* possess several characteristics in common: i.e. subsessile flowers in interrupted spikes, and the usually exserted calyx lobe. As a consequence, weakly pubescent forms of *P. argophylla* are sometimes labeled as *P. digitata*. However, the calyx of *P. digitata* enlarges in fruit; that of *argophylla* does not. This character might suggest the affinities of *P. digitata* to be with the *P. cuspidata-esculenta* group rather than with *P. argophylla*. 
Map 12. Psoralea digitata (squares); Psoralea onobrychis (circles); Psoralea hypogaea (triangles).

Nomenclature:
Psoralea digitata Nutt. in T. and G. Fl. N. Amer. 1:300. 1838.
(2, 3)
P. campestris Nutt. in T. and G. Fl. N. Amer. 1:301. 1838.
(2, 3)
(2, 3)

Nuttall's two names were simultaneously published by Torrey and Gray. Authors have taken up the former, relegating the latter to synonymy.

Psoralea esculenta Pursh (Plate XII. Map 13)
Plants from a pithy, fusiform storage root. Basal portion of caudex with conspicuous ovate scales (stipules). Stems single or two to three, well-developed to very short, simple except for peduncle branches, conspicuously villous-hirsute. Stipules oblong to ovate-oblong, frequently somewhat falcate, to 1.5 cm long. Leaves palmately 5-foliolate; clustered to separate; pubescence on petioles similar to that on stems; leaflets elliptic to ovate; not glandular, undersurface loosely appressed-pubescent, upper glabrate.

Inflorescences axillary, usually arising from lower stem nodes, exceeding or shorter than stems depending upon degree of elongation of latter. Peduncles thick. Spikes dense, to 2.5 cm in thickness. Bracts
Map 13. *Psoralea esculenta* (circles); *Psoralea linearifolia* (squares); *Dalea jamesii* (triangles).

broadly ovate with an acuminate tip, to 1 cm. Flowering calyces about 1 cm, considerably enlarging in fruit, hairy but not glandular; lower tooth the longest, dorsal ones partially fused. Corolla 1.5 cm or more in length, whitish in bud, blue in flower, turning straw-orange with age. Mature fruit with a beak up to 2 cm in length; body papery, entirely enclosed in calyx, beak exserted; body often proximally fragmenting at maturity, the upper portion and beak separating as a unit.

Distribution and habitat. Saskatchewan, Oklahoma, Wisconsin. Prairies, range, hillsides, ridges, knolls, frequently in sand, open pine woodlands in western portion of range. Widely distributed and often common in undisturbed or pastured habitats.

Phenology. Early flowering: May, Missouri and Kansas; June, the Dakotas and Minnesota.

Variability. In the north-central states, *Psoralea esculenta* is ordinarily quite distinctive (less so to the southwest). Nevertheless, it is quite variable in several respects. It is ordinarily caulescent and frequently contrasted with scapose species such as *P. hypogaea* on this basis. However, subscapose specimens are not at all infrequent. I can discern no geographical orientation in their occurrence. The peduncles, 2—several, may originate at approximate nodes near the base of the stem, or alternately on an elongating axis; they may exceed the foliage, or be overtopped by an elongated unbranched leafy stem.

This variability seems in part to be concerned with the degree to which
the vegetative axis elongates (or has elongated at the time a specimen is collected). Apparently the stem continues growth subsequent to flowering; hence, apparent diversity is to a degree spurious, representing only stage of development. I do not know whether the definitely subscapose habit may have a genetic basis, or perhaps reflects unfavorable growing conditions.

Chromosome number. 2n = 22 (Ledingham, 1957).

Discussion. The starchy storage roots of this plant were eaten by the Indians and apparently to a limited extent by early white settlers. This is suggested in various common names attributed to *Psoralea esculenta*: Prairie turnip, Indian breadroot, Indian turnip, Pomme de prairie and Pomme blanche.

Although references to the food value of *P. esculenta* are numerous, unfortunately they appear to be largely derived directly or indirectly from Pursh's description of the species. Pursh's remarks were as follows:

"The present plant produces the famous Bread-root of the American Western Indians, on which they partly subsist in winter. They collect them in large quantities, and if for present use, they roast them in the ashes, when they give a food similar to yams; if intended for winter use, they are carefully dried, and preserved in a dry place in their huts. When wanted for use, they are mashed between two stones, mixed with some water, and baked in cakes over the coals. It is a wholesome and nourishing food, and, according to Mr. Lewis' observations, agreeable to most constitutions, which, he observed, was not the case with the rest of the roots collected by those Indians for food. This root has been frequently found by travellers in the canoes of the Indians, but the plant which produces it has not been known until lately."

Nomenclature:

(P, 2)

*P. esculenta* Nutt. Fraser Cat. 1813, nom. nud. (2, 3)

(1, 2)

The determination of proper author citation for this name raises a somewhat novel question: When is a description a description? Nuttall (loc. cit.) states "The root of this plant is very generally eaten by the savages of the Missourie, and called by the Canadians Pomme de Prairie."

The Rules wisely attempt no definition of a description and many inadequate diagnoses must be accepted as descriptions. Although the above seems fairly definitive, a statement concerning the edible qualities of a plant is probably beyond the spirit of the law, and the name should, thence, be rejected.

Pursh (loc. cit.) does not cite Nuttall, but his illustration is based upon a Nuttall specimen. This was first indicated by Torrey and Gray (1838). Dr. Benner, Acting Curator of Botany of the Philadelphia Academy who has kindly verified this, states (personal communication),
"The Nuttall specimen of *P. esculenta* said by Torrey and Gray to be the basis of Pursh's illustration is here in the Lambert Herbarium. It is a very good picture of the specimen except that the artist omitted certain parts to prevent crowding."

Pursh does cite a Lewis and Clark specimen which unfortunately seems to be a mixture of more than one collection. I am, therefore, basing the name *Psoralea esculenta* upon the Nuttall material.

*Psoralea hypogaea* Nutt. (Plate XIII. Map 12)

Caudices single, subscapose, from a subglobose, short storage root. Stipules papery, to 1 cm, the lower fused to petiole base. Leaves approximate, usually with 5 leaflets, conspicuously appressed-hairy. Leaflets narrowly elliptic or obovate, usually 5–6 mm wide. Peduncles very short or approximating leaves in fruit, strigose. Inflorescence a dense, short spike. Bracts ovate-acuminate. Flowers 12–14 mm; calyx 10 mm or less. Corolla violet. Pod conspicuously beaked.

Distribution and habitat. New Mexico, Texas, Nebraska. High plains. Local or rare.

Phenology. May, June.

Circumscription. *Psoralea hypogaea* is easily defined in the north-central states. This is not true south of our range. The southwestern elements of the complex are in part usually referred to another species, *P. scaposa* (Gray) MacBride. There is, however, congruence of opinion neither as to the status of *P. scaposa*, nor as to the differences between it and *P. hypogaea* (e.g. MacBride, 1922; Tharp and Barkley, 1945; Shinners, 1951; Turner, 1960). The problem awaits further study.

Chromosome number. 2n = 22 (Turner, 1956). Turner more recently (1960) has assigned this determination to *P. scaposa*.

Discussion. This species has the same general aspect as the more common *P. esculenta*. It differs in its subscapose habit and appressed pubescence.

Nomenclature: (limited to elements occurring in north-central states)


*Psoralea lanceolata* Pursh (Plate XIV. Map 14)

Plants from creeping rootstocks. Stems single or clustered, diffusely branched and often forming bushy clumps; surface inconspicuously strigose, strongly glandular. Leaves mostly palmately 3-foliolate; leaflets various in width, the lower often broad (obovate to elliptic), and the uppermost becoming linear; blades appearing glabrate but with appressed pubescence, strongly punctate with glands various in size. Peduncles intercalary, scarcely exceeding leaves. Flowers in short, continuous spike-like racemes. Bracts inconspicuous, early deciduous. Calyx ca. 2 mm long, not enlarging in fruit; teeth shorter than tube. Corolla 3–4 mm, outer petals usually whitish; keel purple-tipped. Fruit exposed, subglobose with short beak, ca. 4 mm long, strongly glandular; pericarp rigid, not breaking at maturity.
Distribution and habitat. Saskatchewan, Oregon, Arizona, Texas, Kansas. This species occupies a diversity of habitats in different portions of its extensive range. In the north-central states, it is almost invariably found in sand, native prairie, or disturbed areas, bottomlands or sterile, eroded soil; it is aggressive and sometimes considered weedy in moist areas. Abundant in favorable habitats.

Phenology. Early June (Kansas) to July (North Dakota).

Variability and circumscription. Genetic diversity within *Psoralea lanceolata* is evidenced primarily by leaflet width variability. Within the north-central states, populations differ considerably not only in average leaf form but in the degree to which a single plant bears a sequence of increasingly narrow blades from bottom to top. In the southwestern portion of the range of this species, western Kansas to Arizona, narrow-leaved types seem to predominate. On the other hand, in the Pacific Northwest the characteristic phenotype possesses broadly obovate blades. However, this form extends sporadically southwest to Arizona and Nevada.

Some authors have delineated the narrow-leaved types as *P. micrantha* Gray ex Torr.; others believe it not to be sufficiently distinguishable from *P. lanceolata*. The broad-leaved phase is accorded nomenclatural status by most authors, either as a variety or a distinct species; the epithets *scabra* Nutt. in T. and G. and *purshii* Vail have been employed.

A definitive interpretation of these and possibly other infraspecific categories awaits a detailed population analysis. Tentatively, it would
seem difficult to make much of a case for P. micrantha; it is overwhelmed by intermediates as well as single plant foliage variability. Perhaps there is a better basis for Psoralea scabra or purshii. The range of these broad-leaved types is to some degree distinctive. Furthermore, authors have additionally distinguished them from P. lanceolata on the grounds that the pods are woolly. This, however, is a matter of degree. The pods of typical P. lanceolata are quite hairy when young; those of its northwestern congeners are glabrate when mature.

Chromosome number. 2n = 22 (Ledingham, 1957).

Discussion. The perennial underground rootstocks are usually slender rhizomes (?), but I have found plants arising directly from a thick woody caudex or an elongated woody rootstock. The rhizomes may penetrate to a depth of 5—6 feet (observed along creek bluff).

Nomenclature:

Psoralea lanceolata Pursh Fl. Amer. Sept. 475. 1814. (1, 3)
P. elliptica Pursh Fl. Amer. Sept. 741. 1814. (1, 3)
P. arenaria Nutt. Gen. 2:103. 1818. (2, 3)
P. scabra Nutt. in T. and G. Fl. N. Amer. 1:300. 1838. (2, 4)
P. laxiflora Nutt. in T. and G. Fl. N. Amer. 1:299. 1838. (2)

Pursh’s P. lanceolata and elliptica refer to the same species. This was recognized by Nuttall (op. cit.) who coined a new name, P. arenaria, treating P. lanceolata and elliptica as synonyms. Subsequent authors took up P. lanceolata relegating P. elliptica of the same date to synonymy—hence P. lanceolata stands.

Psoralea linearifolia T. and G. (Plate XV. Map 13)

Plant perennial, 1—several feet tall, erect, thinly strigose with numerous, slender ascending branches. Leaves petioled to sessile, mostly 3-foliolate, uppermost with but 1—2 leaflets. Leaflets linear, those on main stem to 4 mm wide, those on branches usually not exceeding 2 mm; both surfaces glandular, the upper strigose, lower puberulent to closely strigose. Racemes axillary, long exserted from subtending leaves, loosely flowered. Flowers 2—3 to each bract, the nodes usually distinctly spaced. Pedicels filiform, to 8 mm. Calyx about 3 mm, strongly glandular, the lower tooth slightly the longest. Corolla 6—8 mm, bluish to lavender; wings and standard subequal, the keel considerably shorter. Fruit with an irregularly compressed elliptic body, strongly glandular upon a tan background, 5—6 mm long; beak tapering, 2 mm in length.

Distribution and habitat. South Dakota, Colorado, Texas. High plains, hills, often in rocky or shallow soil. Of local occurrence.

Phenology. July.

Variability. Psoralea linearifolia is reasonably consistent within the north-central states. Several varieties have been described from Texas.

Discussion. This species, a relative of P. tenuiflora may be easily distinguished by its slender pedicels and narrow leaflets. It is much less common than the latter and is relatively infrequently collected.
Psoralea linearifolia T. and G. Fl. N. Amer. 1:300. 1838. (2, 3)

Psoralea onobrychis Nutt. (Plate XVI. Map 12)
Plants perennial from a woody caudex or rhizome. Stems usually single, essentially simple except for the axillary spikes, sparsely puberulent. Stipules setaceous. Leaves pinnately trifoliolate, well petioled and large. Leaflets ovate to ovate-lanceolate, rounded at base, slightly acuminate towards tip, mostly 3—5 cm wide and twice as long, finely puberulent, minutely glandular. Flowers in long-peduncled spike-like racemes. Bracts small, deciduous. Calyx ca. 2 mm, the lobes shorter than the tube. Corolla 6—7 mm, bluish. Pod about 8 mm long, somewhat compressed, ovate to broadly elliptic with a short, offset beak; pericarp thick, black, irregularly reticulate or ridged and warty.

Distribution and habitat. Indiana, Missouri, Tennessee. Lowland woodlands, riverbanks, thickets, roadsides and open disturbed areas. Usually of local occurrence.

Phenology. July.

Nomenclature:
Psoralea onobrychis Nutt. Gen. 2:104. 1818. (1, 2)
Orbexillum onobrychis (Nutt.) Rydb. N. Amer. Fl. 24:5. 1919. (2)

Psoralea psoralioides (Walt.) Cory (Plate XVII. Map 11)
Plant perennial, arising from a short, slender rhizome which connects with a fusiform taproot. Stems erect, few in a cluster, sparingly branched, with inconspicuous appressed pubescence. Stipules setaceous, 0.5—1.0 cm. Leaves not crowded, pinnately trifoliolate. Leaflets elliptic-lanceolate, mostly 3—6 times as long as wide, punctate or essentially without glands, appearing green but with pubescence similar to that on stems. Peduncles exceeding leaves. Spike relatively compact, loosening somewhat in fruit. Bracts ovate, acuminate to subulate-tipped, conspicuous in bud but early deciduous. Calyx 2—3 mm, deeply toothed, not enlarging in fruit. Corolla 6—7 mm, lavender, the standard with a basal dark spot and the keel purple tipped. Fruit compressed, black, transversely ridged, 3.5—5 mm in height, rounded or somewhat broader than long, slightly asymmetric, the inconspicuous, horizontal beak arising from the corner.

Distribution and habitat. Illinois, Texas, Georgia, Virginia. A wide variety of woodland habitats, roadside thickets, fence rows, less frequently prairie areas, often in sandy soil. Very common in the southern and southeastern portion of range, less so in the north-central states.

Phenology. May and June (north-central states).

Variability. In general, P. psoralioides is moderately variable as to leaflet proportions, degree of inflorescence pubescence, and density of the spikes. Two geographical phases are traditionally recognized by most authors. The "typical" (var. psoralioides) but more restricted form is distinctly glandular: bracts, fruits, and leaves. The broad acuminate bracts are usually persistent until the flowers open. This variety is localized along the southeastern coastal plain. Variety
eglandulosa (Ell.) Freeman, our representative, is less glandular than the above; the bracts are narrower and more quickly deciduous. Some-
what intermediate forms are not infrequent.

Discussion. The first leaves on young shoots emerging from the perennial roots are small and essentially palmately foliolate; the leaflets are nearly as broad as wide and the total appearance suggests a Trifolium.

A plant as widespread and relatively common as this species should perhaps logically possess a good common name. Essentially the only epithet in the literature is "Sampson's Snakeroot." This designation appears to have relatively little popular acceptance.

Nomenclature:
Psoralea psoralioides (Walt.) Cory Rhodora 38:406. 1936. (3)
Hedysarum pedunculatum Mill. Gard. Dict. ed. 8, No.17. 1768. (3)
228. 1817. (3)
Trifolium psoralioides Walt. Fl. Carl. 184. 1788. (3)
P. mellilotoides Michx. Fl. Bor. Am. 2:58. 1803. (3)
Orbexilum pedunculatum (Mill.) Rydb. N. Amer. Fl. 24:7. 1919. (3)

The nomenclatural interpretation of this species follows that of Free-
man (1937). Most prior 20th century treatments employ the specific epithet, pedunculatum. Much 19th century herbarium material is design-
nated P. mellilotoides.

Psoralea tenuiflora Pursh (Plate X. Map 15)
Stems 1—several from a woody rootstock, much branched, low or up to 4 feet tall, thinly or closely strigose, or with spreading pubescence. Lower stipules deltoid, conspicuous, the remainder lanceolate, relatively inevinent. Leaves usually palmately 5-foliolate on lower portion of main stem, becoming 4- and 3-foliolate above, 3-foliolate on branches; lower blades well petioled, upper nearly sessile. Leaflets narrowly to broadly obovate to oblong, strigose beneath, glabrate above; more or less evenly dotted with glands of roughly equivalent size, these considerably less conspicuous below than above.

Racemes well peduncled, the flower clusters widely separated to densely congested. Bracts ovate-deltoid, alternate and widely spaced to crowded and paired. Pedicels 1—2 mm. Calyx 2—3 mm; teeth approxi-
mating length of tube, the lower slightly the longest, the upper two closely associated. Corolla 5—8 mm in length, lavender to violet; standard about as wide as long, obliquely ascending to erect; wings partially articulated; keel dark, about half as long as other petals. Fruit about 8 mm long, with an abruptly tapering short beak; the body roughly elliptic but some-
what asymmetric, slightly compressed, glabrous, conspicuously glandu-
lar.

Distribution and habitat. Montana, northern Mexico, Illinois, Minne-
sota; introduced in Indiana. Habitats various; in our range primarily a plains and prairie species; in diverse soil types; persistent and frequently abundant in unplowed areas despite heavy grazing.
Phenology. Main blooming period late spring (south) and early summer (north). Short, few-flowered secondary racemes may be produced throughout much of the growing season.

Variability and circumscription. *Psoralea tenuiflora* is moderately variable in regard to height, extent of branching, leaflet shape, flower size, and most conspicuously, the degree to which the flowers are crowded in the racemes. It is alleged that in some forms the primary leaves are 3-foliolate and in others 5-foliolate. I suspect that this is to some extent a function of the degree to which the lower leaves are preserved on herbarium specimens, and possibly also of vigor of individual plants. It is also stated in most treatments of this species that the flowers per bract range from 1—2 (as in "typical" *tenuiflora*) to 2—4 or more per bract (as in *P. floribunda* T. and G.). There seem to usually be 2—3 flowers per bract; a greater number per cluster may be observed when two bracts are subopposite to one another.

The *Psoralea tenuiflora* complex as herein interpreted includes several species or varieties (e.g., Rydberg, 1919-1920 delimits 4 species) of current definition which have been circumscribed on the basis of the above variability or other incidental characters. These include, from the north-central states, *Psoralea floribunda* Nutt. in T. and G. (larger and congested flowers, 2—4 in a cluster) and *Psoralidium batesii* Rydb. (spreading pubescence). Outside of our range are *Psoralea obtusiloba* T. and G. (variably characterized), *Psoralidium bigelovii* Rydb. (broader leaflets) and *Psoralidium youngiae* Tharp and Barkley (I am unable to
interpret the distinctions either from the original description or photograph of the type).

Do these forms represent valid geographical varieties of subspecies? For the most part, probably not. Like most widely distributed species, *P. tenuiflora* is doubtless genetically diverse, and certainly contains numerous ecological and physiologically differentiated populations. Many of these probably possess a specific geographic orientation. However, a given phenotype may, in one portion of the range, represent a fairly valid morphological marker for a particular race or group of races; but similar phenotypes may turn up elsewhere and represent (or constitute a portion of) rather different populations from the genetic standpoint. For example, broad-leaved forms are common in the southwest where they may be treated as *P. bigelovii* but plants of similar appearance (although undoubtedly different genetically) occur elsewhere in the range.

The densely flowered types attributed to *P. floribunda* appear more common in the eastern than the western part of the range. To some degree, there is a correlation between flower size, total number of flowers in the inflorescence and the compactness of this structure, total size and vigor of the plant; one main stem often predominates in the large *floribunda* types while *tenuiflora* (in the restricted sense) is characterized by diffuse branching in which there is no main stem or leader. Perhaps there is linkage between some of these characters; probably they are in part manifestations of degree of vegetative vigor. In any event, the pattern breaks down so frequently that one has difficulty envisaging independent genetic complexes.

Discussion. The character of the underground parts of *Psoralea tenuiflora* is quite varied. The stems may attach directly to an enlarged woody caudex or pass downwards as slender rhizomes which often extend 3—6 inches before attaching to the rootstock. The woody portion is frequently as broad as long, but I have examined material with rootstocks 12—18 inches in length, with a reticulate fibrous bark, all 1/2 inch or more in diameter.

This species is one of the more persistent forbs of unplowed areas of the great plains. It may still be commonly found, often forming extensive stands over considerable areas. Apparently it is not relished by stock since it is often abundant in overgrazed pastures. The vernacular names, scurf pea and wild alfalfa are employed for *P. tenuiflora*.

Fruit set is erratic, at best only a few flowers per inflorescence maturing pods. The midsummer inflorescences usually do not develop fruits.

Nomenclature:

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Source Details</th>
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<tbody>
<tr>
<td><em>Psoralea tenuiflora</em> Pursh</td>
<td>Fl. Amer. Sept. 475. 1814. (1, 2)</td>
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<tr>
<td><em>P. floribunda</em> Nutt. in T. and G. Fl. No. Amer.</td>
<td>1:300. 1838. (2)</td>
</tr>
<tr>
<td><em>P. obtusiloba</em> T. and G. Fl. N. Amer.</td>
<td>1:300. 1838. (1, 2)</td>
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<tr>
<td><em>Psoralidium bigelovii</em> Rydb. N. Amer. Fl. 24:15. 1919.</td>
<td>(2)</td>
</tr>
<tr>
<td><em>Psoralidium floribundum</em> (Nutt.) Rydb. N. Amer. Fl. 24:15. 1919.</td>
<td>(1, 2)</td>
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<tr>
<td><em>Psoralidium tenuiflorum</em> (Pursh) Rydb. N. Amer. Fl. 24:15. 1919.</td>
<td>(1, 2)</td>
</tr>
<tr>
<td><em>Psoralidium obtusilobum</em> (T. and G.) Rydb. N. Amer. Fl. 24:16. 1919.</td>
<td>(1, 2)</td>
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</table>
Psoralidium batesii Rydb. Brit. 1:91. 1931. (2)
Psoralidium youngiae Tharp and Barkley Bull. Torr. Club
73:131. 1946. (1, 2)

The synonymy of this species is largely a consequence of its morphological diversity.

Synonyms and Rejected Species

Amorpha croceolenta P.W. Wats. A member of the _A. fruticosa_ complex with tawny pubescence on young twigs and under-surface of leaves. Palmer (1931) has reported it from southern Missouri and Illinois. These reports have been echoed in subsequent floristic treatments. I have consigned this form and others enumerated below, to _A. fruticosa_. These decisions should be regarded as tentative because, as indicated earlier in this manuscript, a monographic study of _Amorpha_ by another author is current. Therefore, I have attempted no critical evaluation of the _A. fruticosa_ group.

Amorpha fragrans Sweet. Referred to _A. fruticosa_ L.
Amorpha microphylla Pursh. Equals _A. nana_ Nutt.
Amorpha nitens Boynton. Reported from Illinois by Palmer (1931) and subsequently by Gleason (1952) and Fernald (1950). I am following Gambill (1953) in rejecting _A. nitens_ and treating all material seen as _A. fruticosa_.

Amorpha tennesseensis Shuttl. A southeastern form reported from Missouri (Palmer, 1931). Treated, at least as far as Missouri material is concerned, as an element of the _A. fruticosa_ complex.

Amorpha virgata Small. Reported from Illinois by Palmer (1931). All material seen is referable to _A. fruticosa_ as herein defined.

Dalea alopecuroides Willd. Referred to Dalea leporina (Ait.) Bullock.
Dalea compacta Spreng. Equals Petalostemon compactum (Spreng.) Swezey.

Dalea laxiflora Pursh. Equals Dalea enneandra Nutt.
Kuhnistera Lam. Referable to Petalostemon as a whole or in part dependent upon taxonomic judgement. The name is older than Petalostemon but the latter in the broad sense has been conserved.

Orbexilum Raf. Referred to Psoralea.
Orbexilum onobrychis (Nutt.) Rydb. Equals Psoralea onobrychis Nutt.
Orbexilum pedunculatum (Mill.) Rydb. Equals Psoralea psoralioides (Walt.) Cory.

Parosela Cav. Synonymous with Dalea Juss., the latter conserved.
Parosela alopecuroides (Willd.) Rydb. Referred to Dalea leporina (Ait.) Bullock.

Parosela aurea (Pursh) Britt. Equals Dalea aurea Nutt. ex Pursh.
Parosela enneandra (Nutt.) Britt. Equals Dalea enneandra Nutt.
Parosela lanata (Spreng.) Britton. Equals Dalea lanata Spreng.
Parosela leporina (Ait.) Rydb. Equals Dalea leporina (Ait.) Bullock.
Parosela nana (Torr.) Heller. Equals Dalea nana Torr.
Pediomelum Rydb. Referred to Psoralea.
Pediomelum esculentum (Pursh) Rydb. Equals Psoralea esculenta Pursh.
Pediomelum hypogaeum (Nutt.) Rydb. Equals Psoralea hypogaea Nutt.
ex T. and G.

Petalostemon candidum var. oligophyllum (Torr.) Herm. Equals P. occidentale (Heller) Fern.


Petalostemon molle Rydb. Referred to P. purpureum (Vent.) Rydb.

Petalostemon oligophyllum (Torr.) Rydb. Equals P. occidentale (Heller) Fern.

Petalostemon porteri Small. Gates (1940) refers material from four Kansas counties to this name. The specimens are relegated to P. tenuifolium Gray.

Petalostemon pulcherrimum (Heller) Heller. This primarily Texas species has been reported from both Missouri and Kansas by Rydberg (1932) and the writer has seen several specimens from these states so designated. The specimens are all referred to P. purpureum (Vent.) Rydb.

Petalostemon stanfieldii Small. An Oklahoma - Texas complex reported from Finney County, Kansas by Gates (1940). I have examined the Kansas material, but am unable to distinguish it from P. purpureum. P. stanfieldii is rejected as far as the north-central states are concerned.

Petalostemon tenue (Coult.) Heller. This name appears to represent material of, or related to, the P. stanfieldii group. It is attributed to Kansas by Rydberg (1932) and Gates (1940)—the latter "fide Rydberg." It is rejected on the same basis as P. stanfieldii.

Petalostemon violaceum Michx. Equals P. purpureum (Vent.) Rydb.

Psoralea collina Rydb. Referred to Psoralea argophylla Pursh.

Psoralea floribunda Nutt. Referred to Psoralea tenuiflora Pursh.

Psoralea micrantha Gray. Referred to Psoralea lanceolata Pursh.

Psoralea pedunculata (Mill.) Vail. Equals Psoralea psoralioides (Walt.) Cory.

Psoralea stipulata Pursh. An apparently extinct species of southern Indiana and adjacent Kentucky reported in many older treatments. There are relatively few collections and the latest are about 100 years old. Although its appearance suggests that it is a relative of P. onobrychis, it is glandless and has never been collected in fruit. Therefore, its determination as a Psoralea is not definitive.

Psoralidium Rydb. Referred to Psoralea.

Psoralidium argophyllum (Pursh) Rydb. Equals Psoralea argophylla Pursh.

Psoralidium batesii Rydb. Referred to Psoralea tenuiflora Pursh.

Psoralidium collinum (Rydb.) Rydb. Referred to Psoralea argophylla Pursh.

Psoralidium floribundum (Nutt.) Rydb. Referred to Psoralea tenuiflora Pursh.

Psoralidium lanceolatum (Pursh) Rydb. Equals Psoralea lanceolata Pursh.

Psoralidium linearifolium (T. and G.) Rydb. Equals Psoralea linearifolia T. and G.
Psoralidium micranthum (Gray) Rydb. Equals Psoralea micrantha Gray.

Psoralidium tenuiflorum (Pursh) Rydb. Equals Psoralea tenuiflora Pursh.

LITERATURE CITED


Indiana Dept. of Conservation, Indianapolis.


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1 Pages to 360 published in 1838. Remainder of text in 1840.
Plate I. *Amorpha*

*Amorpha canescens* 1. Fruiting calyx x 3. 2. Flowering branch x 1/3.
Plate II. Amorpha

Amorpha nana  1. Fruiting calyx x 3.  2. Fruiting branch x 2/3.
Amorpha fruticosa  3. Fruit x 2.  4. Flowering branch x 2/3.
Plate III. Dalea

*Dalea aurea* 1. Inflorescence and habit x 2/3. 2. Fruit x 3. 3. Calyx x 3.
*Dalea lanata* 4. Habit x 2/3.
Dalea enneandra  1. Inflorescence x 1\(\frac{1}{2}\).  2. Flower (open and spread) to show petal attachment x 6.
Dalea leporina  3. Habit x 2/3.  4. Calyx x 3.
Plate V. Dalea

Dalea jamesii 1. Habit x 1.
Dalea nana 2. Calyx x 3. 3. Habit x 2/3.
Plate VI. Petalostemon

_Petalostemon candidum_ 1. Habit x 1/3. 2. Bract x 7. 3. Calyx x 7.
Plate VII. Petalostemon

Petalostemon compactum 1. Inflorescence and leaves x 2/3.
Petalostemon occidentale 2. Bract and calyx x 7. 3. Habit x 2/3.
Plate VIII. *Petalostemon*


*Petalostemon foliosum.* 5. Inflorescence and leaves x 2/3.
Plate IX. Petalostemon

**Petalostemon tenuifolium** 1. Inflorescence x 2/3. 2. Calyx x 7. 3. Bract x 7.
Plate X. *Psoralea*

*Psoralea cuspidata* 1. Habit x 2/3.

*Psoralea tenuiflora* 2. Inflorescence x 2/3. 3. Fruit x 2.

4. Lower stem leaf x 2/3.
Plate XI. *Psoralea*

*Psoralea digitata* 1. Habit x 2\(\frac{2}{3}\). 2. Flower x 2.
Plate XII. *Psoralea*

*Psoralea esculenta* 1. Habit x 2/3. 2. Fruiting calyx x 2.
Plate XIII. Psoralea

Psoralea hypogaea 1. Habit x 2/3.
Plate XIV. Psoralea

Psoralea lanceolata 1. Habit x 2/3. 2. Fruit x 2\(\frac{1}{2}\).
Psoralea argophylla 3. Flower x 3. 4. Habit x 2/3.
Plate XV. *Psoralea*

*Psoralea linearifolia* 1. Habit x 2/3.
Plate XVI. *Psoralea*

*Psoralea onobrychis* 1. Leaf and inflorescence x 2/3, 2. Fruit x 3.
Plate XVII. *Psoralea*

*Psoralea psoralioides* 1. Habit x 2/3. 2. Fruit x 5.
CONTINUOUS REARING OF EUROPEAN CORN BORER LARVAE ON ARTIFICIAL MEDIUM

A.J. Becton, B.W. George, and T.A. Brindley

ABSTRACT. Larvae of the European corn borer (Ostrinia nubilalis (Hübner)) were reared through 11 generations on an artificial medium. The procedure involved the use of corn leaf and whorl fractions of the corn plant, mold inhibitor, poured medium, and the direct placement of first instar larvae on the diet. Borers reared on this medium produced moths that appeared normal and deposited a satisfactory complement of eggs.

The need for larvae of the European corn borer, Ostrinia nubilalis (Hübner), in the evaluation of various experimental treatments has prompted the development of several techniques for the rearing of this insect. Some methods, such as those described by Surany (1957), involved the use of fresh or living plant material. Though satisfactory, such techniques are time-consuming and cumbersome. Therefore, development of an artificial medium, which did not contain fresh plant material, but which was adequate for supporting normal growth and reproduction of the corn borer, was investigated. Bottger (1942) developed a synthetic medium for use in nutrition studies. Beck, Lilly and Stauffer (1949) modified this diet and described a successful technique for laboratory rearing of the borer. In a later publication, Beck (1953) indicated that several generations of borers had been raised on the artificial medium with no apparent loss of vitality. However, except for the paper of Wressel (1955), little attention has been given to the use of this diet in a mass-rearing program, and no data have been presented to indicate growth responses of larvae reared continuously on an artificial diet. The purpose of the experiments described here was to develop media and methodology for use in a mass-rearing program and to determine growth.

1 Accepted for publication August 9, 1962. Journal Paper No. J-4393 of the Iowa Agricultural and Home Economics Experiment Station, Ames. Projects No. 1193 and 1140. This investigation was supported in part by a research grant from the Rockefeller Foundation. (Co-leaders, T. A. Brindley, L.H. Penny, and Ernest Wenkert.) The authors gratefully acknowledge the help of F. F. Dicke and other staff members of the U.S.D.A. Corn Borer Investigations Laboratory at Ankeny, Iowa.
2 Now Giegy Agricultural Chemicals.
4 Iowa State University of Science and Technology, and Entomology Research Division, Agric. Res. Serv., U.S.D.A.
responses of the borers after they had been reared continually on an artificial medium for several generations.

Methods

The egg masses and larvae used in these tests were obtained from progeny of field collected larvae. They were collected in the fall, placed in screen-top vials with moist blotter paper strips, and held in a cold room at 45°F until after January 1 of the following year. Then, periodically as egg masses were needed, larvae were placed in an 80°F incubator until pupation. The resultant pupae were placed in clean cages of the type recommended by Mr. F. F. Dicke, entomologist, Corn Borer Entomology Research Division, Agric. Res. Serv., USDA, Ankeny, Iowa (in personal communication). The resulting female moths laid eggs on waxed paper placed on 1/4" mesh screen which served as the top of the cages. First eggs were obtained about 10 days after the larvae pupated. The egg masses were collected daily from the cages and incubated at approximately 81°F. Upon reaching the early blackhead state, the egg masses were either digested apart and placed on the diets after the method of Beck and Stauffer (1950) or placed in individual containers and allowed to hatch. The newly hatched larvae were placed on a diet within 1 hour after hatching.

Diet Preparation

The method used to mix the diet is similar to the one described by Beck et al. (1949). A beaker containing the agar and one-half of the water was placed in a boiling water bath, and the agar solution mixed slowly for 5 minutes. Then the remaining diet ingredients were added, and the resulting mixture stirred for 15 minutes in the boiling water bath. After cooking, the diet was poured into an aspirator bottle with a bacteriological bell attached to the side arm by a 12-inch piece of rubber tubing. By placing a spring clamp above the bell and elevating the aspirator bottle, the diet was introduced into the 3-dram rearing vials from the aspirator bottle by gravity flow. Air pressure was introduced into the bottle to increase the rate of flow of the viscous diet. After filling, the vials were plugged with cotton, and the diet was allowed to cool and harden. In order to facilitate feeding by the first instar borer, a channel was made down one side of the hardened medium with a small spatula.

Mold Inhibitors

It was not desirable to use the aseptic technique of Beck and Stauffer (1950) for mass rearing of larvae. Since Earle et al. (1959) had eliminated the use of aseptic handling procedures in the rearing of the boll weevil by the addition of sorbic acid and methyl p-hydroxybenzoate to the growth media, sorbic acid and n-butyl p-hydroxybenzoate (Butoben) were investigated for possible use in a corn borer diet. Beck et al. (1949) used Butoben successfully. The levels tested of each were: sorbic acid at 0, 0.5, 1.0, and 1.5%; and Butoben at 0, 0.2, 0.4, and 0.6% of the wet weight of the diet. Also, the mold inhibitors were tested at all possible combinations of the above-listed levels. They were compared in a factorial design with 10 replications. The number of borers in each replication ranged from 2 to 4, with a total of 25 borers being
The borers were put on the diet in the egg stage and incubated at 85°F at a relative humidity of 65 to 95%. All of the larvae were weighed on the 10th day after being placed on the diet, then returned to the vials and allowed to pupate. The criteria used to determine treatment effect were larval weight, length of larval period, percent pupation, percent of the young larvae failing to survive after hatching, and the percent of the vials of medium which became visibly contaminated. Oviposition data were not taken because of the small numbers of individuals used in each replication and treatment.

The diet used in this experiment is essentially that given in Table 1 except for variations in mold inhibitor concentrations. Alfalfa leaf meal was used as the "leaf factor," and mold inhibitor combinations were added as described earlier. A brief summary of the results of this experiment are given in Table 2. As can be seen from this table, neither chemical alone was capable of suppressing the growth of all microorganisms except in concentrations which also affected larval development.

Table 1. Composition of the diet.

<table>
<thead>
<tr>
<th>Amount used (gms)</th>
<th>Dry diet (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carrier:</strong></td>
<td></td>
</tr>
<tr>
<td>Distilled water</td>
<td>255.00a</td>
</tr>
<tr>
<td>Bacto-Agar</td>
<td>6.60</td>
</tr>
<tr>
<td></td>
<td>12.6</td>
</tr>
<tr>
<td>Glucose</td>
<td>10.50</td>
</tr>
<tr>
<td>Casein, vitamin-free b</td>
<td>10.50</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>0.85</td>
</tr>
<tr>
<td>Corn oil containing 1% alpha tocopherol</td>
<td>0.50</td>
</tr>
<tr>
<td>Salts mixture No. 2, U.S.P. XIII b</td>
<td>1.30</td>
</tr>
<tr>
<td>Choline chloride</td>
<td>0.12</td>
</tr>
<tr>
<td>Brewers yeast U.S.P.</td>
<td>6.90</td>
</tr>
<tr>
<td>Leaf factor</td>
<td>13.80</td>
</tr>
<tr>
<td></td>
<td>26.3</td>
</tr>
<tr>
<td>Mold Inhibitor Mixture: c</td>
<td></td>
</tr>
<tr>
<td>n-butyl p-hydroxybenzoate</td>
<td>0.60</td>
</tr>
<tr>
<td>Sorbic acid</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>1.1</td>
</tr>
</tbody>
</table>

a Plus 10% to compensate for evaporation during cooling
b Nutritional Biochemicals, Inc., Cleveland, Ohio
c Added in 95% ethyl alcohol

The combination of 0.2% Butoben and 0.5% sorbic acid allowed the most rapid development of larvae with good control of microorganisms. This combination showed some detrimental effect on hatching and larval survival, so a combination of 0.2% Butoben plus 0.2% sorbic acid of the wet weight of diet was used in all future work and gave very satisfactory results.
Table 2. Effects of mold inhibitor combinations on borer development.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Larval weight at 10 days (mg)</th>
<th>Length of larval period (days)</th>
<th>Pupation (%)</th>
<th>Contaminated (%)</th>
<th>Failed to hatch (%)</th>
<th>Failed to survive (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butoben</td>
<td>0^a</td>
<td>18</td>
<td>49.6</td>
<td>18.0</td>
<td>66.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Sorbic acid</td>
<td>0</td>
<td>18</td>
<td>49.6</td>
<td>18.0</td>
<td>66.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Butoben</td>
<td>1.5</td>
<td>6</td>
<td>25.1</td>
<td>21.2</td>
<td>83.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Sorbic acid</td>
<td>1.5</td>
<td>6</td>
<td>25.1</td>
<td>21.2</td>
<td>83.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Butoben</td>
<td>0.6</td>
<td>7</td>
<td>16.8</td>
<td>21.2</td>
<td>71.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Sorbic acid</td>
<td>0.6</td>
<td>7</td>
<td>16.8</td>
<td>21.2</td>
<td>71.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Butoben</td>
<td>0.2</td>
<td>19</td>
<td>40.2</td>
<td>18.8</td>
<td>89.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Sorbic acid</td>
<td>0.5</td>
<td>19</td>
<td>40.2</td>
<td>18.8</td>
<td>89.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

^aPercent of wet weight of diet
Plant Fractions

These tests were designed to determine if any growth response differences were evident with the use of different corn plant fractions as the "leaf factor" in the diet modified from Beck et al. (1949). Leaf, whorl, tassel, "soft dough stage" kernel and whole plant of the corn borer susceptible inbred, WF9, were the plant fractions tested for growth and reproduction responses. Also popcorn and sweet corn kernels were tested. All fractions of WF9, other than tassel, were harvested when the plant reached an extended height of 40 inches. The plant parts were placed on a rack made of poultry wire and were placed in the sun and air dried. They were then ground in a Wiley mill using a 2 mm mesh perforated screen. The coarse powders were then placed in a forced ventilation, hot air drying oven at 100°F and left for 72 hours. They were ground again in the Wiley mill, this time using a 0.5 mm mesh screen, then stored at -4°F until used.

In the first studies, fractions were tested in concentrations of 8, 15, and 26% of the dry weight of the diet. It was learned that the best response was obtained from the diets containing the higher concentration of plant fractions. Therefore, in the later studies involving the use of soft dough stage sweet corn kernel and popcorn tassel, only the higher concentrations (26%) were used. Fifty larvae were started on each diet and incubated as described. They were replicated across all treatments. Each replication consisted of larvae from only one egg mass to allow for the variation due to differences between egg masses. Usually five or more replications were required to place larvae on all diets. Twenty-five larvae from each treatment were weighed on the 10th day after being placed on the medium, after which they were returned to the vials to pupate. The pupae were removed from the vials, placed in oviposition cages and allowed to emerge. Oviposition data were recorded. After the death of all adults in the oviposition cages, the adults were counted and their sex determined. The number of pupae failing to emerge properly (failing to become free of the pupal case or wings not expanded) was recorded. Thus the four major criteria used to determine treatment effect were larval weight, length of larval period, number of adults emerging properly, and the number of egg masses per female.

In interpreting the results of the experiments using oviposition as the criterion, it is recognized that the population densities and sex ratios within the cages were not identical. The exact effect these variations had on oviposition is not known. Therefore, these figures should be viewed with some reservation. The tests of concentration utilized only fractions from the inbred line WF9. Selected portions of the concentration tests are given in Table 3 and are illustrated in Figure 1. As can be seen from this figure and the table, each fraction or combination of fractions gave a better response with each increase up to 26% of the dry diet. This response was also seen in tests of tassel, tassel plus leaf, tassel plus whorl and whole plant tissue which were run concurrently. The "leaf factor" level of 26% of the dry diet was adopted for the following series of tests to determine the optimum combination of fractions.

Twelve fractions and combinations of fractions were tested as "leaf factor" sources. These were alfalfa, WF9 leaf, whorl, tassel, whole plant, leaf plus whorl, leaf plus tassel, whorl plus tassel, sweet corn
Table 3. Effect of plant fraction concentration on borer development.

<table>
<thead>
<tr>
<th>Plant fraction concentration</th>
<th>Mean larval weight (mg)</th>
<th>No. of larvae weighed</th>
<th>Length of larval period (days)</th>
<th>Emergence (%)</th>
<th>No. adults female</th>
<th>Masses per female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>49.8</td>
<td>20</td>
<td>15.1</td>
<td>78.8</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Leaf</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8%</td>
<td>38.2</td>
<td>20</td>
<td>17.3</td>
<td>87.2</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>15%</td>
<td>62.0</td>
<td>16</td>
<td>14.9</td>
<td>94.3</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>26%</td>
<td>73.2</td>
<td>18</td>
<td>14.7</td>
<td>97.4</td>
<td>21</td>
<td>17</td>
</tr>
<tr>
<td>Whorl</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8%</td>
<td>24.3</td>
<td>18</td>
<td>19.2</td>
<td>37.0</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>15%</td>
<td>34.0</td>
<td>19</td>
<td>17.0</td>
<td>38.7</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>26%</td>
<td>43.6</td>
<td>19</td>
<td>15.3</td>
<td>67.5</td>
<td>8</td>
<td>19</td>
</tr>
<tr>
<td>Leaf and whorl</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8%</td>
<td>37.9</td>
<td>16</td>
<td>16.5</td>
<td>63.3</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>15%</td>
<td>62.0</td>
<td>15</td>
<td>15.5</td>
<td>100.0</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>26%</td>
<td>90.5</td>
<td>16</td>
<td>14.4</td>
<td>100.0</td>
<td>14</td>
<td>16</td>
</tr>
</tbody>
</table>

"soft dough stage" kernel, popcorn tassel, and popcorn tassel plus WF9 leaf. Data on the significant tests are included in Table 4. The remainder of the tissues tested produced inferior growth and/or reproduction and have been omitted from the table. These data indicate that a half-and-half WF9 leaf and whorl mixture produced more rapid larval growth than the other fractions and, with the exception of the WF9 leaf and popcorn tassel mixture, produced moths from which the highest egg production was recorded. Since the leaf and whorl mixture resulted in the best over-all results, it was adopted for the continuous rearing diet.

Continuous Rearing

The corn borer has been reared for three successive years in the laboratory to determine the dietary requirements that will satisfy the long-term needs for maintaining vigorous stocks for experimental studies throughout the year. The first attempts to raise larvae terminated in loss of the cultures after six generations. Subsequent attempts have been remarkably successful, and the methods are given here.

The diet used is given in Table 1 and the method of preparation was described above. The method of inoculation of vials varied as the work progressed. In earlier work, sterile eggs were placed individually in the vials. In later generations, egg masses were allowed to hatch in a moist container and the young larvae were picked up on a narrow spatula and placed in the vials, two to a vial. This reduced the mortality very markedly. At 3 days, vials with dead larvae were discarded; at 10 days, the vials containing "runts" (slow growing larvae) were discarded.
Figure 1. Effects of different corn plant fractions at differing concentrations on larval weight at 10 days.
Table 4. Effect of various plant fractions on borer development.

<table>
<thead>
<tr>
<th></th>
<th>Larval weight (mg)</th>
<th>No. of larvae weighed</th>
<th>Length of larval period (days)</th>
<th>Emergence (%)</th>
<th>No. moths</th>
<th>No. egg masses</th>
<th>Masses per female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa(^a)</td>
<td>49.9</td>
<td>19</td>
<td>14.5</td>
<td>68.6</td>
<td>9</td>
<td>15</td>
<td>55</td>
</tr>
<tr>
<td>Leaf</td>
<td>73.4</td>
<td>18</td>
<td>14.1</td>
<td>97.4</td>
<td>21</td>
<td>17</td>
<td>155</td>
</tr>
<tr>
<td>Whorl</td>
<td>43.7</td>
<td>19</td>
<td>14.7</td>
<td>67.5</td>
<td>8</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>Tassel</td>
<td>32.4</td>
<td>18</td>
<td>18.4</td>
<td>96.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Whole plant</td>
<td>49.0</td>
<td>21</td>
<td>14.9</td>
<td>85.3</td>
<td>17</td>
<td>12</td>
<td>36</td>
</tr>
<tr>
<td>Leaf and whorl(^b)</td>
<td>90.8</td>
<td>16</td>
<td>15.9</td>
<td>100.0</td>
<td>14</td>
<td>16</td>
<td>176</td>
</tr>
<tr>
<td>Leaf and tassel</td>
<td>55.4</td>
<td>16</td>
<td>16.4</td>
<td>93.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Whorl and tassel</td>
<td>44.4</td>
<td>18</td>
<td>16.9</td>
<td>81.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Corn meal(^c)</td>
<td>30.2</td>
<td>19</td>
<td>18.8</td>
<td>17.2</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Tassel(^d)</td>
<td>38.5</td>
<td>25</td>
<td>19.6</td>
<td>53.4</td>
<td>14</td>
<td>6</td>
<td>49</td>
</tr>
<tr>
<td>Tassel(^d) and leaf</td>
<td>63.5</td>
<td>25</td>
<td>16.7</td>
<td>83.0</td>
<td>19</td>
<td>15</td>
<td>280</td>
</tr>
<tr>
<td>Tassel(^d) and whorl</td>
<td>35.9</td>
<td>25</td>
<td>18.4</td>
<td>45.0</td>
<td>2</td>
<td>17</td>
<td>3</td>
</tr>
</tbody>
</table>

\(^a\) All fractions were added at the rate of 26% of dry diet

\(^b\) Combination fraction diets were mixed at the rate of 13.8 gm total with each fraction making up one-half of the total

\(^c\) Sweet corn kernel

\(^d\) Popcorn tassel lopop 6
Records then were taken on the number of days to first pupation and on larvae failing to pupate in 20-21 days. Pupae were placed in sterile cages for emergence of moths and egg laying. After oviposition records had been completed, the cages were opened. The numbers of males and females were determined, and unsuccessful emergence and pupal mortality were noted.

The results of the continuous rearing through 11 generations are given in Table 5. Data on alternate generations of one of the two cultures which were maintained concurrently are given here to indicate results to be expected from the use of an artificial medium. The number surviving remained quite uniform, and the number of egg masses per female was satisfactorily uniform considering the difficulties in determining what constitutes a single egg mass.

Table 5. Summary of data on continuous rearing of European corn borer on artificial media. Ames, Iowa, 1960-61.

<table>
<thead>
<tr>
<th>Generation</th>
<th>Number of larvae at 10 days</th>
<th>Pupation No.</th>
<th>Pupation %</th>
<th>Emergence No.</th>
<th>Emergence %</th>
<th>Number of egg masses per female</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>157</td>
<td>110</td>
<td>70.1</td>
<td>10.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>179</td>
<td>159</td>
<td>88.8</td>
<td>126</td>
<td>79.2</td>
<td>17.0</td>
</tr>
<tr>
<td>V</td>
<td>265</td>
<td>199</td>
<td>75.1</td>
<td>139</td>
<td>69.8</td>
<td>6.9</td>
</tr>
<tr>
<td>VII</td>
<td>270</td>
<td>242</td>
<td>89.6</td>
<td>168</td>
<td>69.4</td>
<td>10.6</td>
</tr>
<tr>
<td>IX</td>
<td>243</td>
<td>217</td>
<td>89.3</td>
<td>158</td>
<td>72.8</td>
<td>6.9</td>
</tr>
<tr>
<td>XI</td>
<td>156</td>
<td>115</td>
<td>74.1</td>
<td>90</td>
<td>78.3</td>
<td>7.1</td>
</tr>
</tbody>
</table>

This technique, utilizing mold inhibitors, poured medium, and direct placement of first instar larvae on the medium, has provided quite adequate numbers of insects for the needs of this laboratory. Slight modifications of technique should provide sufficient numbers for a large-scale laboratory program.

REFERENCES


The theses are listed in alphabetical order by names of authors. Each listing includes the name of the author, the title of the thesis, and the department(s). 

ADAMS, CLARK FRANCIS  
A steady-flow governor and throttle controlled fuel-injection system for automotive engines.  
Mechanical Engineering

ALMQVIST, JAMES CHARLES  
Degrees to which an Iowa county extension program planning-steering committee met selected criteria.  
Economics and Sociology

ANDERSON, ANDREW JOHN  
Ion drifted solid state scintillation counters.  
Electrical Engineering

ARCHER, JEAN NEMORIN  
Age changes in the gastric mucosa of the domestic pig.  
Veterinary Anatomy

ARENDT, BILLY DEAN  
Bounds for the number of non-isomorphic groups of given order.  
Mathematics

ASKELSON, CURTIS EVERETT  
Influence of age and dietary protein on certain free amino acids in chick blood plasma.  
Poultry Science

ASSAF, WALID CONSTANTINE  
Gamma radiation scattering and attenuation properties of Barites concrete.  
Nuclear Engineering

AZIZ, AKBAR  
Insulation considerations in the design of transmission lines.  
Electrical Engineering

BARACCO, NESTOR PEDRO  
Effects of row spacing and population levels on the performance of four corn inbreds in single cross hybrids.  
Agronomy

BATTIKH, HANI KHALIL  
Effect of some rare earth chlorides on development in the chick.  
Zoology and Entomology

BAUMANN, DONALD PAUL  
The enumeration of psychrophilic microorganisms in dairy products.  
Bacteriology: Dairy and Food Industry

BEAVER, JOHN PHILLIP  
Magnetic properties of europium-ytterbium alloys.  
Physics

BEELER, MARY ESTHER  
Qualifications for managers of single unit and directors or supervisors of multiple unit school lunch programs.  
Institution Management

BERLIN, JAQUES ARKIN  
Analysis of insecticides by fortified bioassay.  
Zoology and Entomology

BERLIN, LORNA CHUMLEY  
The morphology and salivary enzymes of the digestive system of the potato leafhopper, Empoasca fabae (Harris).  
Zoology and Entomology

A circulating copy of each thesis is available in the Iowa State University Library. A microfilm or a photostatic copy of a thesis may be purchased from the Iowa State University Library, Ames, Iowa.
Besson, Marcos
Effect of climatic and soil factors on response of mixed meadow to phosphorus fertilizer. *Agronomy*

Bieenberg, Betty Marie
Factors related to professional interest of home economics students and teachers. *Home Economics Education*

Birowo, Achmad Tunggul
Use of linear programming for farm planning guidance. *Economics and Sociology*

Boatman, James Claude
Synthesis and reactions of some reduced tantalum halides. *Chemistry*

Bolstad, Roger Ardel
Ring-necked pheasant and pheasant habitat in central Iowa. *Zoology and Entomology*

Boteler, John Clarence
An exploratory study of a mass spectrometric diffusion technique. *Physics*

Brown, John Barclay, Jr.
Irradiation of thin magnetic films. *Nuclear Engineering*

Brown, Margaret Evelyn
Intake of fat by women on self-selected diets. *Food and Nutrition*

Brown, Roberta Gomes
Studies on the relationship of dietary carotene and nitrogen sources in rats. *Food and Nutrition*

Bunch, Ronald James
High levels of copper oxide and copper sulfate in swine rations. *Animal Science*

Bush, Glenn
Relationships between ecclesiastical success and church sponsored activity programs. *Economics and Sociology*

Cainelli, Cesare
Optimum resource allocation on farms in the Argentina corn belt. *Economics and Sociology*

Carlson, Keith Joseph
Corals of the Gilmore City limestone, Iowa. *Geology*

Cavanah, Charles Edward
Use of corncobs in phenolic plastics. *Chemical Engineering*

Chantalakhana, Charan
Estimates of genetic parameters of carcass traits in swine. *Animal Science*

Chaudhri, Dhruvi Chhaya
Beliefs and practices of Iowa county extension home economists regarding program planning. *Home Economics Education*

Chinniah, Kamala Thummala
An inventory for measuring mothers' attitudes toward learning experiences for children in the management of money. *Home Management*

Circeo, Louis Joseph, Jr.
Strength-maturity relations of soil-cement mixtures. *Civil Engineering*

Clark, Alfred James
Protein and energy levels in swine rations. *Animal Science*

Clovier, Everett Leroy
Opportunities for establishment of young farmers in farming in the Webster City community school district. *Vocational Education*

Condos, Apostolos
International transmissions of income and growth. *Economics and Sociology*

Conzemius, Robert Joseph
Analysis of carbon monoxide-nitrogen mixtures by high resolution mass spectrometry. *Chemistry*
COTTS, DAVID GEORGE
Analysis of the movement of a divisional artillery unit.
Civil Engineering

COWAN, CHARLES DE HART
Source size and brightness errors caused by phase-shifter losses in the radio interferometer.
Electrical Engineering

COX, RODNEY EDGERTON
Effect of loess filler upon bituminous concrete containing Iowa aggregates.
Civil Engineering

CREGER, WILLIAM ELLERY
Parking study for the central business district of Ames, Iowa.
Civil Engineering

CUNNING, JOE DAVID
Specific gravity measurement of nonpolar gases by electrical capacitance.
Chemical Engineering

DAGADU, JULIANA MAUD
Nutritional status with respect to thiamine and riboflavin of selected foreign students.
Food and Nutrition

DANGORIA, DEVENDRALAL C.
Solubility of wheat gluten in various reagents.
Chemical Engineering

DAVIDSON, GARY ARTHUR
A compact electronic system for experimental physiology.
Electrical Engineering

de BACA, MARY ADENA
Factors associated with family decisions involved in building new farm houses.
Home Management

DEBU, FRENY ERUCH
Learning of perceptual-motor tasks by preschool children under three conditions.
Child Development

DEONIER, DICK LEE
The shore flies of Iowa (Diptera, Ephydridae).
Zoology and Entomology

DESAI, JYOTI AMBELAL
Development of an instrument to measure image of home management.
Home Management

DICKEN, HOWARD KEITH
The fabrication of semiconductor devices from magnesium silicide.
Electrical Engineering

DILLMAN, NORMAN GREGG
Experimental determination of electrical parameters of ionic solutions.
Electrical Engineering

DOERFLER, THOMAS EUGENE
The compounding of gradient error in the method of parallel tangents.
Statistics

DOIDGE, JEROME GEORGE
A thin magnetic film multiplier.
Electrical Engineering

DORN, VIRGINIA N. STUCK
Consumer and retailer differences in recognition of factors influencing retail prices of women's coats.
Textiles and Clothing

EASTON, ROBERT HUNT
Large-volume manometric apparatus for oxygen-uptake studies.
Civil Engineering

EDGAR, CHARLES ERNEST, III
Use of the Iowa State drop hammer apparatus in the study of moisture-density relations of soils and soil-cement.
Civil Engineering

EDMONDS, CLINTON JAMES
Effect of loading rate and particle size on sewage sludge digestion.
Civil Engineering

EICHACKER, RICHARD CHARLES
Industrial arts merit badges earned by Iowa eagle scouts.
Vocational Education

ELLENA, EMILIO
Estimation of a corn forecast equation from a cluster sample.
Statistics
ELSON, CHARLES EDWARD
Influence of age on characteristics of porcine muscle.
Animal Science

EWING, KEITH LOWELL
Linear relation between age and selected hematological values of the C57BL/6 Jax mouse.
Zoology and Entomology

FAAS, RICHARD WILLIAM
Micropaleontology of some quaternary sediments from the Barrow area, northern Alaska.
Geology

FELBINGER, ROBERT JOHN
The effects of differential levels of early handling upon adult socio-sexual behavior in the albino rat.
Psychology

FLAUGH, HARRY LEE
Design and performance of a compact mixer-settler extractor.
Chemical Engineering

FOGELMANIS, ANDRIS
Application of composite designs in fitting quadratic response surfaces.
Statistics

FOLLOSCO, CEFERINO LIM
Fluid factors affecting the flow rate of agricultural spray nozzles.
Mechanical Engineering

FOWLER, JAMES LEE
Use of the dog as a test animal for detecting staphylococcal exenterotoxin.
Veterinary Medicine

FRIGERIO, OCTAVIO OSCAR
Factors which influence weaning weight of beef calves.
Animal Science

GABRIELSON, JAMES EARL
Effect of diatomite coating agents on the drying of nitrogenous fertilizers.
Chemical Engineering

GILL, JOHN LESLIE
Effects of environmental factors upon feed lot gains and carcass traits in beef cattle.
Animal Science

GOBEN, CHARLES ALVIN
A transistorized, wide-band pulse amplifier.
Electrical Engineering

GOEDERS, CALVIN NICHOLAS
Effect of structure on direction of elimination in pyrolysis of organic esters.
General Science: Teacher Education

GOODRICH, DON MERTON
A comparison of three methods of attitude scale construction.
Psychology

GOROSZKO, FRANCIS EDWARD
The ratio of photodeuterons to photoprotons from cobalt.
Physics

GREENE, RICHARD GEORGE
Ion exchange separations of lead.
Chemistry

GRIFFEN, DANIEL L.
Engineering valuation decisions in Iowa and other states.
Industrial Engineering

GROENE, ROBERT FRANCIS
Economic implications of continuous row-cropping in Iowa.
Economics and Sociology

GUZMAN, ALBERTO
Solubility of triglycerides in ethanol.
Chemical Engineering

HAIGHT, CHARLES ORRAMELL
Observations on the effects of sodium glutamate, sodium succinate and L-arginine·HCl on ammonia intoxication in lambs.
Veterinary Physiology and Pharmacology

HAILEY, NANCY WINSTON
Factors associated with friendships of pre-adolescents.
Child Development

HANKS, LELAND FARRIES
Aerial volume tables for Iowa hardwoods.
Forestry
HANSON, THOMAS LARS
Comparison of synthetic storm hydrographs for selected rainfall patterns.
Agricultural Engineering

HARBRON, THOMAS RICHARD
Design of a small, electronic, automatic, digital computer.
Electrical Engineering

HEARN, JUNE LOVELESS
Life history antecedents of measured personality variables.
Psychology

HEGLAND, DONALD EUGENE
Magnetization and electrical resistivity of terbium single crystals.
Physics

HEIFNER, MARJORIE MARTIN
Effects of selected commercial cleaners on three types of kitchen floors.
Household Equipment

HEIN, DALE ARTHUR
Roosting flight counts as indices to fall wood duck populations in Iowa.
Zoology and Entomology

HENDRICKSON, HOWARD TILFORD
Altitude-hold control system study using combined digital and analog techniques.
Electrical Engineering

HILDEN, SPENCER HARLOW
A longitudinal analysis of migration of young adults, Hamilton County, Iowa.
Economics and Sociology

HOOTMAN, JOALLAN
One-half watt transistorized 118 to 136 megacycle power amplifier.
Electrical Engineering

HORRIGAN, VIRGINIA MARY
The determination of oxygen in rare earth fluorides.
Chemistry

HUHN, KEMPION LEROY
An expression for the Newtonian gravitational potential of an oblate spheroid.
Mathematics

HUGHES, BENJAMIN GLENN
Reactions of some niobium (V) halides with pyridine.
Chemistry

HUSTED, WILLIAM LOREN
Vocational Education

IRVINE, WILLIAM ARDEN
Infection of woody plant roots by Armillaria mellea.
Botany and Plant Pathology

JAHNKE, ALDEN WAYNE
Feasibility study of establishing a moon base.
Civil Engineering

JAMAL, HUDA
Sex-role identification in preschool children.
Child Development

JAMES, SUZANNE TRUEDELL
Stability of average intelligence.
Psychology

JENKINS, QUENTIN ARTHUR LOT
A statistical analysis of risk preference and traditionalism scales.
Economics and Sociology

JOHNSON, ARNOLD FREDERICK
Audio frequency measurement using a monostable multivibrator.
Electrical Engineering

JOHNSON, MILDRED VIRGINIA
Criteria for a home economics organization in a school system.
Home Economics Education

JOHNSON, WORNEY JOHN, JR
Roles, personality and performance of individuals in a selected extension program planning group.
Economics and Sociology

KANIUKA, RUSSELL PAUL
History of the Iowa State University Press.
Technical Journalism

KASSIR, SAMI MAJEED
Relative effectiveness of various anti-frothing agents for pasture bloat therapy.
Animal Science
KERR, JAMES FRANKLIN  
Effect of chemical growth regulators on development of the crown rust fungus in detached leaves of oats.  
Botany and Plant Pathology

KHÄLF-ALLAH, ABDEL AZIZ  
A comparison of selection methods for improvement of yield, earliness, and fruit size in the tomato.  
Horticulture

KHAN, RIAZ AHMAD  
An evaluation of farm credit cooperatives with special reference to the U.S.A. and India.  
Economics and Sociology

KIDWELL, MARGARET MARY  
Variation among commercial strains of chickens in loss of internal egg quality.  
Poultry Science

KILLAM, JAMES PAUL  
Prediction of achievement at Maine township high schools in selected industrial arts areas.  
Vocational Education

KIM, YOUNG SOOK  
Labor time, equipment time, and yield for three methods of preparing turkey in institution food service.  
Institution Management

KJÄR, RAYMOND ARTHUR  
Transient characteristics of p-n-p-n triodes.  
Electrical Engineering

KLEPPNER, JAMES STEPHEN  
Investigation of an equilibrium model for fixed bed ion exclusion.  
Chemical Engineering

KOMASA, NOEL JOSEPH  
Ratings of high school course areas by farm male graduates in nonfarm occupations.  
Vocational Education

KRISTIANSEN, DONALD MELVIN  
Factors influencing the distribution of judgments and the judgment of neutrality on an equal-appearing interval scale.  
Psychology

KRISTIANSON, BRYANT NEIL  
Gamma radiation from neutron absorption in niobium.  
Nuclear Engineering

KRIÉ, GEORGE JAMES  
Pumping irrigation wells for drainage of Luton soils.  
Agricultural Engineering

LACEY, CLARENCE JOHN  
An acoustical delay system for video signals.  
Electrical Engineering

LAMBERT, HOWARD WILSON  
Compactness and product spaces.  
Mathematics

LANEY, WILLIAM STÄRÄ  
Stabilization of selected ungraded aggregates with foamed asphalt.  
Civil Engineering

LA ROSE, JOSEPH ARTHUR, JR.  
Destructive distillation of carbonaceous Iowa shale.  
Chemical Engineering

LARSEN, MELVIN B.  
Iowa county highway maintenance practices.  
Civil Engineering

LAUER, WILLIAM JAMES  
Reproduction of air flow patterns in a scale model of an elementary classroom.  
Architectural Engineering

LEJDE, INGE KURT ALLAN  
Estimation of optimum farm size in the Götaland forest area of Sweden.  
Economics and Sociology

LEIBHOLZ, JANE MATHILDE N.  
Effect of manganese on several tissue measurements and on performance of swine.  
Animal Science

LENTNER, MÄRVIN MEINRAD  
Inferences concerning the scale parameters of two gamma distributions.  
Statistics

LEVINE, LAWRENCE HARVEY  
Kinetic studies of L-amino acid oxidase.  
Chemistry
LILLEHOJ, EIVIND B.
Properties of the myrothecium ascorbic acid oxidase.
Botany and Plant Pathology

LIPIS, ALLEN HERBERT
Noisy duels as limits of game iterations. Statistics

LOMEN, DAVID ORLANDO
Application of the Mellin transform to boundary value problems. Mathematics

LU, YAO-CHI
Effect of diversification on price and income stability in livestock production.
Economics and Sociology

LUECK, PHYLLIS ELIZABETH
Ability of young children to execute tracing and cutting tasks.
Child Development

LUSTIG, PAUL HERBERT
Transfer function of UTR-10 reactor using reactor oscillator technique. Nuclear Engineering

MAC BRIDE, GEORGE DEXTER
Prediction of first year achievement for Ames High School graduates at Iowa State University. Vocational Education

MADRAMOOTOO, HARRY
Rural youth clubs in agricultural extension in British Guiana. Vocational Education

MENDOZA, CELSO ENRIQUEZ
Biological evaluations of inbred black cutworm, Agrostis ipsilon. Zoology and Entomology

MEYER, WILLIAM HENRY
Life history of three species of redhorse (Moxostoma) in the Des Moines River, Iowa. Zoology and Entomology

MICHIGAN, EDMOND GEORGE
Quantum mechanical treatment of a particle moving in a 3-dimensional central potential. Physics

MILLER, WILLIAM GEORGE
Homosexual behavior of incarcerated females. Psychology

MILLHAM, CHARLES BlanchARD
Games related to stochastic linear programs. Mathematics

MUIR, ROBERT MARTIN
A small magnetic memory for display of transients. Electrical Engineering

MUNTZ, DAVID CARL
Hydraulic performance of a peripheral feed settling tank predicted by model studies. Civil Engineering

MC CRACKEN, JOHN DAVID
Relation of high school vocational agriculture to achievement in college courses in agronomy. Vocational Education

MC GINNIS, ROBERT LEE
Kinetics of coupled reactor cores using six groups of delayed neutrons. Nuclear Engineering

MC GRATH, FRANCIS JOHN
Set properties induced by subsets of lesser cardinality. Mathematics

MC MULLEN, WILLIAM D.
A study of the yttrium-rich portion of the yttrium-oxygen system. Metallurgy

MCrackEN, JOHN DAVID
Relation of high school vocational agriculture to achievement in college courses in agronomy. Vocational Education

MC GINNIS, ROBERT LEE
Kinetics of coupled reactor cores using six groups of delayed neutrons. Nuclear Engineering

MC GRATH, FRANCIS JOHN
Set properties induced by subsets of lesser cardinality. Mathematics

MC MULLEN, WILLIAM D.
A study of the yttrium-rich portion of the yttrium-oxygen system. Metallurgy

MENDOZA, CELSO ENRIQUEZ
Biological evaluations of inbred black cutworm, Agrostis ipsilon. Zoology and Entomology

MEYER, WILLIAM HENRY
Life history of three species of redhorse (Moxostoma) in the Des Moines River, Iowa. Zoology and Entomology

MICHIGAN, EDMOND GEORGE
Quantum mechanical treatment of a particle moving in a 3-dimensional central potential. Physics

MICK, DAVID LEE
Growth and development of three alfalfa varieties in relation to leaf area, leaf position, and net assimilation rate. Agronomy

MILLER, WILLIAM GEORGE
Homosexual behavior of incarcerated females. Psychology

MILLHAM, CHARLES BLANCHARD
Games related to stochastic linear programs. Mathematics

MUlR, ROBERT MARTIN
A small magnetic memory for display of transients. Electrical Engineering

MUNTZ, DAVID CARL
Hydraulic performance of a peripheral feed settling tank predicted by model studies. Civil Engineering

MAYCOCK, PAUL DEAN
Thermal diffusivity measurements on a finite disk. Physics
MURRAY, DONALD CARLTON
Heat transfer between stratified immiscible liquids in counter-current flow.  Chemical Engineering

MYKLEBUST, ROBERT LEE
The manganese-yttrium phase diagram.  Chemistry

NAKATSUGAWA, TSUTOMU
Activation of organophosphates by insect tissues.  Zoology and Entomology

NELJBERGER, EDWIN PAUL
Effect of oxygen on mechanical properties of niobium.  Metallurgy

NEWTON, MELVIN FRASIER
Factors influencing occupational choices of farm-reared male graduates of Newton High School.  Vocational Education

NICHOLS, RICHARD LEE
The moment-ratio method of analyzing industrial property experience.  Industrial Engineering

NICKERSON, GENE ARTHUR
Reduction of the noise level from the tilting arbor table saw.  Vocational Education

NIELSEN, LORRAINE THOMSON
Personal-social problems recognized by Iowa boys and girls in grades 8-12, 1960.  Home Economics Education

NIEMAN, MARY READ
Effectiveness of the placement test for sectioning students in the elementary clothing construction course.  Textiles and Clothing

NORTHEY, WILLA VERENA
Differentiation among first-year homemaking teachers by student estimates of teacher concern.  Home Economics Education

NUTTER, JAMES IRVING
Variation of mass transfer zone with inlet air moisture content in fixed adsorbent beds.  Chemical Engineering

OLSON, FRANCES AVONNE
Cinema-analysis of infant reactions after stress as related to type of mothering.  Child Development

PACKARD, JAMES RUSSELL
An experimental equation of state for solidified xenon.  Physics

PAŃEK, RICHARD EDWARD
Relation between autokinesis and introversion-extraversion.  Psychology

PARKER, ARLEY VERN
The response of a vibrating system to several time dependent frequency excitations.  Mathematics

PECHIN, WILLIAM HARRIS
Phase equilibria in the zirconium-cobalt system.  Nuclear Engineering

PECKHAM, JOHN CECIL
Comparison of classical rickets with osseous changes in baby pigs fed a ration deficient in D vitamins.  Veterinary Pathology

PELLETT, HAROLD MELVIN
Effects of nitrogen, phosphorus, and potassium on summer growth recessions of Kentucky bluegrass.  Horticulture

PETELEW, LARRY JAMES
A quarterly model of the egg marketing economy.  Economics and Sociology

PFEIFF, THEODORE HARLAN
History of industrial arts in the public schools of Davenport, Iowa.  Vocational Education

PICAUT, JACK GILBERT
Correlations of density, moisture content, sodium chloride content and resistivity of soils.  Civil Engineering
PIERCE, RICHARD BRAYTON
Non-flocculating solids removal in model circular settling tanks. Civil Engineering

PIETRZYKOWSKI, ANTHONY D.
Preparation of 2, 2'-bipyridine and 2', 2''-terpyridine. Chemistry

PINTO, CARLOS DE SOUSA
Stabilization of montmorillonitic soils with lime-cement mixtures. Civil Engineering

PITRE, GEORGE LUKE, JR.
Moisture-density and moisture-strength relationships of cement-treated soils. Civil Engineering

PORTER, ROBERT LEE
Theoretical rationale and methodological development for the study of personality correlates with architectural environment satisfaction. Architectural Engineering

PRAKASH, ANAND
Magnetic lens systems for the synchrotron. Physics

PRELL, PATRICIA ANN
Relation of physical and sensory evaluations of egg quality to age and strain of hens. Food and Nutrition

RAY, EDYTHE KATHRYN
Student attitude change following two types of courses in child development. Child Development

REIGN, LEWIS LINGO, JR.
Development of an apparatus and procedure for evaluating the pumping characteristics of soil. Agronomy

RENEKER, WILLIAM DANIEL
Investigation of the flexural fatigue strength of prestressed steel I-beams. Civil Engineering

RICHARDSON, LOU BETTY
Effects of genetic and environmental variation on chlorophyll, carotene, and xanthophyll levels in seedlings of selected maize mutants. Genetics

RICHARDSON, WILLIAM HOWARD
Number theory of the Gaussian integers. Mathematics

RICHARDSON, WILLIAM HOWARD
The pathology of experimental infection produced by a filterable agent, isolated from a field case of mucosal disease of cattle. Veterinary Pathology

RIDGE, NANCY CHIVERS
Age changes in glycogen content and histology of the mouse liver. Zoology and Entomology

RIGLER, LARRY GEORGE
Effects of conservation reserve participation in southern Iowa. Economics and Sociology

RINGE, LARRY JOEL
The use of an approximation to the beta function. Statistics

ROBERTS, EDGAR DONALD
The pathology of Mycoplasma hyorhinis arthritis experimentally produced in swine. Veterinary Pathology

ROBERTS, HARRY CHARLES
Solubility of dialdehyde starch in various reagents. Chemical Engineering

ROBINSON, JEFFREY ALLAN
Perceptions and experiences of young Iowa farm families who changed residence and occupation. Economics and Sociology

ROGERS, WALLACE A.
Effect of continued selfing on Hymenolepis nana. Zoology and Entomology

RUSSCHER, GLENN EARL
Determination of neutron flux spectrum by thin foil activation. Nuclear Engineering
SANDERSON, DONOVAN FOREST
On the construction of the measurable sets. Mathematics

SAUPE, WILLIAM EDWARD
Farm record analyses as source of farm management guides. Vocational Education

SCHAFER, CAROLYN LOUISE
Measurements of comminuted bovine skeletal muscle subjected to strain. Food and Nutrition

SCHAFER, ROBERT LOUIS
A technique for measuring shear forces of agricultural soils. Agricultural Engineering

SCHAUER, FRANZ PETER
Strength in shear of prestressed concrete I beams with deflected strands. Civil Engineering

SCHMIDT, GERALD JOHN
Relation of high school vocational agriculture and science to achievement in the college of agriculture. Vocational Education

SCHMIDT, WILLIAM HARVEY
Waterfowl, quail, pheasant and deer occurrence along the proposed Saylorville impoundment. Zoology and Entomology

SCHMITZ, RONALD JOHN
A 100-200 megacycle counting circuit. Electrical Engineering

SECREST, BRUCE GILL
Solutions of Laplace's equation in terms of parabolic cylinder functions. Mathematics

SEDLACEK, WILLIAM EDWARD
A factor analysis of personality and attitude correlates of football ability. Psychology

SEYMOUR, EUGENE WESLEY
Effects of protein level and environmental temperature on the performance and carcass quality of swine. Animal Science

SHINDE, SHASHIKALA J.
Vocabulary test on man-made fibers for college students. Textiles and Clothing

SHUTE, ELIZABETH ANNITA
Bromate decomposition in fused alkali nitrates. Chemistry

SILLIMAN, BENJAMIN DUANE
Predicting achievement in mechanical drawing. Vocational Education

SMITH, THOMAS KEITH
Impact factor studies on a small scale laboratory bridge. Civil Engineering

SMITH, WILLIAM ROUSE
Resistor-transistor-tunnel diode logical circuitry. Electrical Engineering

SNYDER, RICHARD LEE
A descriptive study of high school counselors in Iowa. Vocational Education

SODEN, ROBERT EDWARD
Feasibility of a north-south one-way street system for the city of Ames, Iowa. Civil Engineering

STOCK, DAN ALBERT
Removal of chlorine from water with activated carbon filters. Civil Engineering

STURTEVANT, JOAN
Gene frequencies and the efficiency of exclusion in human populations; special reference to the blood groups. Genetics

SWANSON, ROBERT MAGNI
Opportunities for establishment of young farmers in the Marengo, Iowa community. Vocational Education

SWIDAN, MOUSTAFA ALI
Effect of exciter response on A-C generator transients. Electrical Engineering

TEAGLE, CHARLES RAY
Effect of asbestos on asphalt mixes containing Iowa aggregates. Civil Engineering

THATCHER, WILBERT COLIN
Some genetic and environmental influences on weaning and yearly traits of beef cattle in Saskatchewan. Animal Science
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Stochastic processes obeying two or more separate regimes. Statistics

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Abbink, Janet E., joint author, see under Fritz.
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   ____ , joint author, see under Hartman, Huber.
   ____ , joint author, see under Charity.
   ____ , joint author, see under Schaller.
   ____ , joint author, see under Welsh.


38. ____, 1961. The role of nonbonded repulsions in secondary isotope effects. II. Influence on structure; gamma and more distant effects. Iowa State Jour. Sci. 36:137-146.


56. . 1961. How to select hand drills and impact tools. County Agent and Vo-Ag Teacher 17(12).


65. Bernardes, Newton. 1962. On the a-β phase transition of solid He

66. Biester, H. W., joint author, see under Zimmermann.

, Associate Editor. Cornell Veterinarian.
Bird, E. W., joint author, see under Sander.


Black, C. A., joint author, see under Allmaras.


Boast, W. B., joint author, see under Bolie.

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Boles, Donald E., Editor. Iowa Municipal Manual.


84. Brasfield, J.F., joint author, see under Daniels.


91. Bryan, D.E., joint author, see under Knight.


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   joint author, see under Campbell.


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___, Associate Editor. Marriage and Family Living.

___, Abstracts Editor. Marriage and Family Living.

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____, Editorial Committee. AEC-AIBS Monograph "Insects and Insecticides."


Dempsey, M.E., joint author, see under Boyer.

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Discussion of paper by M.O. Withey. Proc. Amer. Concrete Inst. 58:945-946.


Gill, K.J., joint author, see under Chiotti.


   joint author, see under Vance.
   Gunderson, J., joint author, see under Edwards.


   lum metal by the carbon reduction of tantalum pentoxide.

261. Hansen, Louis O. and Roger L. Lawrence. 1962. More training in
   sociology and economics; many opportunities available. Ext.
   Serv. Rev. 33:11-23.

   1962. Reclaiming coal spoilbanks in southeastern Iowa. Iowa

263. Hansen, Robert S. 1961. Diffusion and the kinetics of adsorption of
   aliphatic acids and alcohols at the water-air interface. Jour.
   Colloid Sci. 16:549-560:

264. 1962. Thermodynamics of interfaces between condensed

265. 1962. The electrical double layer around a spherical colloid
   particle (Review of the book by A. L. Loeb, J. T. G. Overbeek,

266. and C. A. Smolders. 1962. Colloid and surface chemistry in
   the mainstream of modern chemistry. Jour. Chem. Educ. 39:
   167-178.

   ability in self-pollinated species with application to the soybean.
   Genetics 46:1425-1434.

268. and . 1962. Analysis of genetic variability from gener-

   fertility. I. Growth of different plant parts, and relation between

270. 1962. Corn growth and composition in relation to soil fer-
   tility. II. Uptake of N, P and K and their distribution in different

   III. Percentages of N, P, and K in different plant parts in relation


Hartl, Neil E., joint author, see under O'Byrne.
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, Bulletin Editor. Research Publications, Iowa Agricultural and Home Economics Experiment Station.

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364. Jensen, T. E, and C. C. Bowen. 1961. Organization of the centro-
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Jones, J. D., joint author, see under Puchal.
magnetic resonance in metal tungsten bronzes. Jour. Chem.
Physics 36:494-499.
____, joint author, see under R. G. Barnes.
ment on body weight and subsequent wool and lamb production of
367. ____ and ____. 1961. Lamb production as affected by forage
mixture and grazing management of perennial pastures. Jour.
____, joint author, see under Wedin.
multistage, fused salt-molten metal extractor. Trans. Amer.
Nuclear Soc., Inc. 4:352.
370. Karas, George G., Sheldon K. Edelman, Steve Zyzanski, and
Don Goodrich. 1961. An analysis of the content of perceptual
68:529-534.
371. ____ , ____, R. J. Farrell and T. E. Dubois. 1961. An experi-
mental comparison of associative responses to two types of
____, joint author, see under Denenberg.
Interaction of photoperiod and vernalization in flowering of
Kassir, S. M., joint author, see under Van Horn.
Kastelic, J., joint author, see under H. L. Chapman, Lowe.
374. Kempthorne, Oscar. 1962. Discussion: on the foundations of
375. ____ and Richard H. Osborne. 1961. The interpretation of twin
376. ____ , George Zyskind, Sidney Addelman, T. N. Throckmorton,
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____, Associate Editor. Annals of Mathematical Statistics.
____, Editorial Associate. Biometrics.


387. Kline, E.A., joint author, see under McIntosh.

388. Klingman, D.W., joint author, see under Banks.

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    ____, Abstract Committee. Geoscience Abstracts.


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____, Editorial Board. Proceedings, Iowa Academy of Science.

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506. Phaff, H.J., joint author, see under M.W. Miller.


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538. Robinson, J. L., joint author, see under Hutchcroft.


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   Editorial Board. Journal of Physical Chemistry.


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Taiganides, E. P., joint author, see under Beer, Willrich.


626. ____. 1962. Mathématiques et statistiques pour les économistes.
   ____, Associate Editor. Metroeconomica.
   ____, Associate Editor. Unternehmungsforschung.
   ____, Associate Editor and Book Review Editor. Econometrica.
   ____, Abstractor. Mathematical Review.
   Tipton, C.L., joint author, see under Carter.

627. Toksoz, Sadik and Don Kirkham. 1961. Yeni bir dren aralığı
   formülüm grafik çözüm ve tefsiri (A new drain spacing
   formula with graphs). Tarim Bankalığı Topraksu (Turkish

   Chapter 20 (pp.216-250) in: Education Television - The Next
   Ten Years. 1st ed. 375 pp. Institute for Communication Res.,
   Stanford University.

   Radio Engr. 50:825-829.

630. ____, and William L. Hughes. 1961. Some comments on the technical
   realities concerning television allocations. Inst. Radio
   Engr. Trans. 7:17-23.

   of coating the canes of dormant rose plants with melted paraffin

   The crystal structure of chromium(II) chloride. Acta Crystallo-
   graphica 14:927-929.

   energies of europium, gadolinium, holmium, and erbium. Jour.
   Tu, Yien-I, joint author, see under Maki.
   Tweeten, L.G., joint author, see under Heady.

   and genesis of soils developed in very firm till in northeastern

635. Ulmer, M.J. 1961. Passerine birds as experimental hosts for
   Posthodiplostomum minimum (Trematoda: Diplostomidae).
   Jour. Parasitol. 47:608-610.

   anatomy—A laboratory manual. 1st ed. 268 pp. Harper and
   Bros.
   Underbjerg, G.K.L., joint author, see under Swenson.


660. ______ and Dwayne Rohwedder. 1962. Time your harvesting for better forage. Iowa Farm Sci. 16:3-4.


Zuech, E.A., joint author, see under Gilman.


____, joint author, see under Kempthorne.

Zyzanski, Steve, joint author, see under Karas.
In the Iowa State Journal of Science, Vol. 36, No. 4, p. 487, the legend for Figure 1 should read as follows:

Figure 1. Seedling reaction to oat stem rust race 13A of C.I. 3039, Richland, and F₄ lines from the cross Richland X C.I. 3039. Leaf pairs are, from left to right, C.I. 3039, C896-2-8 (homozygous resistant), C896-6-30 (segregating), C896-6-31 (homozygous susceptible), and Richland.
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