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Title: The Effect of Methods and Dates of Planting On Establishment, Growth and Yield Potential of *Papaver bracteatum* Lindl.

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Five methods of *Papaver bracteatum* Lindl. stand establishment were tested. They were: 1) direct seeding, 2) direct seeding under a 2.5 cm band of activated charcoal with an associated application of a broad spectrum herbicide for weed control, 3) seedling transplants in Jiffy 7® peat pellets, 4) greenhouse grown root crown cuttings, and 5) directly planted root crown cuttings. These methods were evaluated in fall plantings for two years and in a spring planting for one year. Measurements were made of relative plant vigor, stand survival, total capsule number, total capsule weight, mean number of capsules per plant, mean weight per capsule and seed weight. A cost analysis of the establishment methods was developed.

Relative vigor was not found to be a useful measurement of differences between methods of establishment. This result was due to

the variability in vigor among plants and treatments. Stand survival was an accurate method of gauging yield potential in mature stands. Capsule and stem yields of 443.3 kg/ha were obtained from 22-month-old fall planted, greenhouse grown root crown cuttings. Yields of three of the four spring planted treatments did not differ significantly. The directly planted root crown cuttings were statistically poorer yielding than the other methods. Choice of the best method of establishment for each date of planting cannot be made from the data presented in this thesis.

The cost of establishment method ranged from $290.72 to $3650.00 per hectare. However, it was found that the least expensive method may not be the best. Factors such as weed competition, variability and vulnerability of *P. bracteatum* seedlings as well as other potential stand losses could be important in modifying results from this type of experiment. It was noted that modest economic yields as soon as possible after stand establishment would help defray the initial costs. Results of this study indicate that *P. bracteatum* has the agronomic and economic potential to be commercially grown in the Willamette Valley of western Oregon.

The Effect of Methods and Dates of Planting On Establishment, Growth and Yield Potential of *Papaver bracteatum* Lindl.

by

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THE EFFECT OF METHODS AND DATES OF PLANTING ON ESTABLISHMENT, GROWTH AND YIELD POTENTIAL OF *Papaver bracteatum* Lindl.

I. INTRODUCTION

At present, the world's sources of opium are not adequate to meet the codeine demand (20, 21). In 1974, more than half the opium held for emergency use in the United States' strategic materials stockpile was released to meet the demand for codeine (21).

The United States imports more opium than any other country in the world (4). In 1978, 600,000 kilograms of opium equivalent were imported (4). This figure is expected to rise to 618,000 kilograms in 1979 (4).

Papaver bracteatum has been considered as a potential commercial source of the alkaloid thebaine, which can be used in the production of codeine (20, 21). It has been postulated that this source of codeine could fill the gap between the available supply of opium and the demand for its useful and legal derivatives (20, 21, 25, 26, 27, 29).

The goal of this study was to evaluate several methods of establishment and dates of planting as they affect the growth, establishment and yield potential of *Papaver bracteatum* in western Oregon. An additional goal was to quantify the relative costs of these techniques and to describe how these costs could affect the production of thebaine for use in the manufacture of important pharmaceutical compounds.

II. LITERATURE REVIEW

Plant Characteristics

P. bracteatum is a robust member of the Papaveraceae family, section Oxytona (17). This species is further characterized by the following traits: bud shape oval to oblong; flower buds closely surrounded by five to eight imbricated bracts with coarsely toothed fringes, one at least of which persists after the sepals, petals and stamens have been shed; calyx covered with coarse trichomes; petals, five to six, deep red with one or two black blotches at the base from which black lines extend upward; chromosome number 2n=14 (26).

P. bracteatum as a source of pharmaceuticals differs from the opium poppy, *Papaver somniferum* Linn. in many respects. *P. bracteatum* is a perennial (20, 21, 27). It reaches maximum size and productivity three years after planting (12, 20). Some plants are known to be 15-20 years of age (20). It has been estimated that this plant would remain economically productive for eight to 10 years (14, 23). The equivalent amount of codeine per hectare from *P. bracteatum* is at least three to five times higher than the opium poppy when the plant reaches its full productivity (21). Codeine yields of up to 15 kilograms per hectare have been reported for *P. bracteatum* (14, 27). The costs of cultivation, processing, and conversion of thebaine to codeine has been known to compare favorably with the cost of utilizing opium, and less than the cost of utilizing opium straw.

P. bracteatum does not produce opium or morphine (20, 21, 26). It produces relatively large quantities of the alkaloid thebaine which can be converted to codeine. It thus has the potential for supplying the world's total demand for codeine (20). Since the plant requires three years to mature, it is thought that illegal production of *P. bracteatum* would be very difficult (20, 21).

Adaptation

P. bracteatum grows wild in three separate areas of the Middle East. The largest population is in the Alborz Mountains in the north and northwest of Iran on slopes facing the Caspian Sea (17). This group was designated Arya I upon discovery of a second population (27). The second Iranian population is located in the Kurdistan region of western Iran (17). This group was designated Arya II (27). A third population occurs on the north-facing slopes of the Caucasus Mountains in the U.S.S.R. (17).

This species is adapted to relatively dry situations. It often occurs on stony slopes between 1500 to 2000 meters above sea level in association with a depauperate cushion-type vegetation (17).

The seed from mature plants is dispersed by the action of the wind on the seed pods. The seed may germinate in the fall or lie dormant until spring. After the seed germinates, it grows vegetatively until the dry weather during the summer causes it to become dormant. This dormancy may last two or more months, ending with the initiation of fall rains. In the fall, the plants begin their vegetative growth which continues slowly throughout the winter. The plant grows vigorously during the spring and flowers in May or June. *P. bracteatum* plants generally produce one flower in the first year, one to five flowers the second year, and five to 20 flowers from the third year on. The seeds are considered mature four to six weeks after the petals drop but it may take another two weeks for them to fully ripen (12, 13, 14, 15, 27, 29, 31).

P. bracteatum is adapted to a wide variety of climates, soil types, and pH (6, 7, 19, 26, 28). Seedlings have grown well in clay clay-loam, loam and sandy soils, but produce poorly in sandy soils with low organic matter (12, 28). *P. bracteatum* has been successfully grown in soils ranging from pH 4.6 to 10.0 (6, 7, 19, 26, 28), but it does best in a soil with a neutral pH (7.0)(26). The salts affecting the pH are more important to crop growth than the measured pH values (28). Sodium seems to inhibit germination (28).

The water requirements of *P. bracteatum* vary with the type of soil, amount of wind, and prevailing temperatures. However, it has been noted that, once established, the water requirements were low compared to other crops since *P. bracteatum* derives water from deep in the soil profile (28). In Oregon, it has been found that spring seeded *P. bracteatum* requires irrigation throughout the summer months (12). During the first three to four weeks after planting, one-half inch of water, sprinkler applied, is required every three days. After the seed has germinated and the young plants are established, this requirement drops to one-half inch of water per week (12). For fall seeding, one-half inch of water is required every three days until the plants are established or until the first fall rains.

Cultural Practices

Fertility

The level of fertility affects the growth and thebaine content of various parts of the plant (26). However, workers disagree on the reasons for these effects (11, 12, 24, 30). Workers in France indicate that optimum growth and thebaine yields were obtained from yearly applications of equal amounts of nitrogen, phosphorus, and potassium at 150 kilograms of each per hectare (31). Results of a fertility study in Oregon indicate that maximum yields can be obtained by a pre-plant application of 50 kilograms of nitrogen and phosphorus per hectare incorporated into the soil before planting. Maintenance applications of 50 kilograms of nitrogen per hectare broadcast applied in the fall to established poppies was found to be sufficient to sustain vegetative growth and yields.

Weed Control

Weed control on *P. bracteatum* is essential (25). Calhoun and Crane found that seeding poppies under a 2.5 cm band of activated charcoal followed immediately by an application of diuron [3-(3,4-dichlorophenyl)-1,1 dimethylurea] at 1.8 kilograms per hectare of active ingredient gives satisfactory weed control for a year or more (12, 29). However, it is recommended that yearly fall applications of diuron or simazine [2-chloro-4,6-bis(ethylamino)-*s*-triazine] at 2.25 kilograms per hectare active ingredient affords the best weed control (12). Glyphosate [N-(phosphonomethyl)glycine] at 1.0

kilograms per hectare active ingredient may be needed during the summer dormancy to control perennial weeds (7, 8, 10, 12).

Methods of Establishment

Seeding

As with most crops, it is important to have good quality seed with a high germination rate. The seed will germinate at temperatures ranging from five to 30°C (22, 31). Temperatures above 25°C have been found to be detrimental, and no germination occurs at 35°C (1). The most uniform and vigorous germination occurs between 15 and 20°C (1, 22, 27, 28, 31, 32). At these temperatures, the seed will germinate in two to three weeks (22). The best germination in the field occurs at 15°C (28, 29). Lower temperatures delay germination (28, 29).

Maximum and minimum temperatures play an important role during the first year of establishment. Temperatures of -10°C or below without snow cover and of 40°C or above will kill plants. However, the plants can be protected from such temperature extremes by mulches or coverings (29).

Direct field seeding has the advantage of being the least expensive method of establishing *P. bracteatum*, but the young plants are very small and vulnerable to changes in the weather and moisture conditions. This results in highly variable seedling emergence (22). A planting depth of 1/2 cm in a very firm seedbed has resulted in the best stands (28, 29). Direct field seedings may require thinning and replanting to get the desired stand of plants (16).

Evidence has shown that direct sowing of *P. bracteatum* is practical if effective weed control methods are used and adequate moisture is provided during germination and seedling establishment (29, 30). Direct seeding under a 2.5 cm band of activated charcoal followed by an application of a broad spectrum herbicide was found to be the most effective method of direct seeding (29, 30).

Field seeding - spring: Calhoun and Crane found that the best time for direct seeding of *P. bracteatum* was in the spring (25). No differences were found in total capsule yield in harvest year 1977 of poppies sown on April 7, April 27, and June 8 of 1976 (9). Poppies seeded in the spring grew more vigorously and had a higher rate of survival than those sown during the summer or fall (25). Poppies planted in the spring generally flower and produce one or two capsules the following summer (16).

Field seeding - fall: Fall seeding of *P. bracteatum* in western Oregon produced the best stands and had the highest winter survival rate when sown in August (7). Plants established in the fall did not flower or produce capsules the following spring (7). Variability of weather conditions at this time of year often make fall seeding impractical or impossible. Further problems may also arise due to the fragility of the young seedlings.

Greenhouse-grown transplants: *P. bracteatum* seedlings can be grown from seed planted in the greenhouse. After four to six weeks, these seedlings may be transplanted into the field. In most circumstances, the young plant and a portion of the growing medium are transplanted as a unit (16). The use of greenhouse-grown transplants seems to be the most successful method of field establishment of *P. bracteatum*. One can assume an average success transplant survival rate in the field of 80 percent or higher (16).

The United Nations reported that transplants four weeks of age or older were easily established in the field and were slightly larger at the end of the first growing season than direct seeded plants (39). Jones and Fairbairn, however, found that direct seeded plants will grow as large as the transplants after the first year (29). Transplants were found to produce capsule yields equal to those of plants established by direct seeding under activated charcoal (7).

Seedlings produced in the greenhouse and transplanted into the field without the medium in which they were grown have been tried. While costs of production are lower and the greenhouse space needed to produce this type of seedling are less than other transplants, their average success rate when transplanted into the field is much lower than other types of seedling transplants (16).

Vegetative Propagation

Vegetative propagation of *P. bracteatum* has been investigated by several authors and was, in general, found to be too expensive, difficult, and impractical for commercial production (12, 16, 23, 28, 29).

Lavie reports better growth from longitudinal root cuttings than from transverse cuttings (28). Transverse cuttings of roots below the crown will also produce plants (29). In making his cuttings, Lavie made a transverse cut about ten cm below the crown. The resulting section of root and crown was then cut longitudinally into five or six wedges which were three or four mm in thickness (28). Cuttings were made from the roots of two- or three-year old plants just prior to the end of the dormancy period in September or October. Cuttings were placed in moist sand for initiation of growth (28). Each cutting had at least one microscopic bud which produced a good plant within three months after cutting and, when planted in the field, bloomed the following summer (29). Crane and Pumphrey reported similar findings (12, 23). Cuttings made in March or April, when the plants were actively growing, had a very poor rate of survival (29).

Harvest and Yield Potential

Harvest of *P. bracteatum* should occur when both the thebaine content is highest and the seed is fully mature (28). Time of harvest is usually four to six weeks after the petals fall (12, 14, 15, 27). At this point, the capsules are dry, light green, or yellow in color, and the seed rattles freely in the capsule when agitated (12). The capsules and peduncles can be mechanically harvested (9, 10, 20). After combine-harvesting, the plant material can be milled to break the capsules and release the seed, the seed separated, and the straw stored up to one year before extraction (20). Straw yields of between 4000 and 7000 kilograms per hectare are thought to be possible in mature plants, which would yield 40-70 kilograms per hectare of thebaine (14, 27).

III. MATERIALS AND METHODS

Field studies were initiated in 1977 at Hyslop Agronomy Farm in Corvallis, Oregon to investigate establishment of *Papaver bracteatum* in western Oregon. The soil is a Woodburn silt loam (fine, silty, mixed mesic Aquultic Argixerol). The weather conditions for the two cropping seasons are summarized in Appendix Tables 1 and 2.

The germplasm used in this experiment was U.S.D.A. PI 383309. The seed originated in the Alborz Mountains of Northern Iran (Arya I). The seed was originally supplied by the United Nations Secretariat, Division of Narcotic Drugs to the United States Department of Agriculture, Plant Introduction Station workers in Pullman, Washington. Seed used was obtained from established plants at Central Ferry, Washington that were harvested in 1975. The plants from which the root crown cuttings were made were established at Hyslop Farm in 1976, utilizing the above seed source. All seed was cleaned prior to planting, utilizing an Oregon Vibrator Cleaner to remove any foreign material and shrunken or broken seed.

Three plantings were made during the ensuing two years. The experimental design was a randomized complete block with four replications of each method of establishment.

Plantings were made in three row plots. Each row was 3.66 meters long with 60 centimeters between rows. All plots were thinned or planted to one plant per 30 centimeters of row. All data were collected from the center row of each plot. The remaining plant material was included to allow for border effects.

The seedbed was prepared prior to planting by plowing, discing, and harrowing.

Fertility was insured by preplant application of 336 kilograms per hectare of 16-20-0 in the fall and a subsequent spring application of 56 kilograms per hectare of ammonium sulfate (21-0-0-245).

First year weed control was maintained by cultivation. All the plots subsequently received a fall application of diuron at 1.8 kilograms per hectare of active ingredient.

Germination was tested prior to every date of planting. Two 50-seed samples were plated on absorbent paper in petri dishes at room temperature (± 20°C) for two weeks. Counts were made at the end of that period and percent germination calculated.

The methods of establishment used in this study were as follows:

Direct seeding: Seed was planted directly in the soil with a Planet Junior® seeder and thinned to one plant per 30 cm of row.

Direct seeding under charcoal: Seed was planted directly in the soil as above with addition of a 2.5 cm band of agricultural grade activated charcoal sprayed over the seed row. The charcoal was applied utilizing a 7.6 liter tank mounted on the seeder and connected to a flat-fan nozzle approximately five cm above the surface of the soil. Directly after planting, this plot was sprayed with diuron at 1.8 kilograms per hectare active ingredient.

Seedling transplants in peat pellets: Seeds were planted in Jiffy 7® peat pellets. Jiffy 7 peat pellets are obtained as dehydrated, pre-fertilized discs containing finely ground peat in a plastic mesh. Upon soaking in water, they expand to 3.5 cm in diameter and five cm in height and are then ready for planting. The seedlings were grown in the greenhouse for six weeks before being thinned to one plant per pellet and transplanted into the field.

The greenhouse conditions that prevailed during the six-week growth period of the seedlings and cuttings were as follows: a 12-hour daylength was maintained under artificial light; temperature was maintained at 20°C during the day and 17°C at night; watering was done every three days or as needed.

Planting of pellets was accomplished by digging a hole five cm deep in the soil approximately 6.5 cm in diameter with a bulb planter. The pellet was then placed in the hole to the base of the crown and soil loosely filled in around it.

Greenhouse grown root crown cuttings: Root crown cuttings were made by digging an entire plant, removing any loose soil from the roots and then making a transverse cut six cm below the crown. After this transverse cut was made, the resulting piece was cut longitudinally into four to 16 wedges, each of which was one cm thick. Care was taken to make sure each cutting included part of the crown. The cuttings were then placed vertically, with the portion of crown exposed, in horticultural grade perlite. The number of cuttings that rooted in the greenhouse was recorded at the time of planting. The cuttings were grown in the greenhouse for six weeks before planting under the same conditions as described above.

Directly planted root crown cuttings: Root crown cuttings of the same dimensions as above were made the day of planting and placed directly in the field (spring and fall 1978 only). The plants used for the fall plantings were dug from the field in the last week of August before they broke summer dormancy. The plants were placed in a bucket of water and stored at 5°C for up to one-half hour to prevent desiccation prior to preparing the cuttings for planting.

Plants used for the spring plantings were actively growing at the time they were dug to make the cuttings. The plants were 23 to 46 cm in height and in full leaf. The leaves were trimmed to one cm above the crown to prevent desiccation due to transpiration. The roots were divided and planted as previously described.

Table 1. Dates of planting of *P. bracteatum*.

	Treatment				
Time of Planting	Direct Seeded	Direct Seeded Under Charcoal	Transplants in Peat Pellets	Greenhouse Grown Root Crown Cuttings	Directly Planted Root Crown Cuttings
Fall 1977	Oct. 10	Oct. 10	Dec. 5	Nov. 10	---[a]
Spring 1978	May 8	May 8	May 8	Failed to root	May 10
Fall 1978	Aug. 30 Replant Sept. 22	Aug. 30 Replant Sept. 22	Nov. 1	Nov. 1	Nov. 1

[a]This method not used in fall 1977 planting.

The fall 1977 planting was rated for relative vigor on the following dates: May 3, May 10, and October 18 of 1978 and at the time of harvest in July 1979. Relative vigor and number of plants per plot was recorded for the fall 1978 planting on April 13 and May 10 of 1979. The spring 1978 plantings were rated for vigor and number of plants per plot on June 30 and October 18 of 1978 and May 13 and July 13 of 1979.

Relative vigor was rated on a scale of one to ten. The plant or plants that appeared most vigorous in terms of number of leaves, color, turgidity of leaves, and plant height were assigned a ten and the others rated by comparison.

In order to evaluate the relative straw and seed yields of each plot, the following measurements were made at the time of harvest or calculated afterwards: total capsule number, total capsule weight, number of capsules per plant, weight per capsule, and total seed weight per plot.

All plots were hand-harvested. The seed capsules along with 15 cm of peduncle were clipped from each plant when fully mature. Plants were considered mature when the seed would readily shake free from the capsule if agitated. After harvest, the capsules were emptied of seed and the various measurements were made and recorded.

Data was analyzed using the analysis of variance for a randomized complete block design as described by Little and Hill (18). Means were subsequently compared using Duncan's multiple range test (18).

IV. RESULTS AND DISCUSSION

Establishment

Five methods of establishment of *P. bracteatum* were investigated to evaluate the effect on growth and development of this species in western Oregon. The methods of establishment used in this study were: direct seeding, direct seeding under activated charcoal, seedling transplants in peat pellets, greenhouse grown root crown cuttings, and directly planted root crown cuttings. Plant survival and relative vigor were used for evaluation of stand establishment.

Fall 1977. Both direct seeded treatments in the Fall 1977 planting failed to survive the winter. The lack of survival of these plots was seemingly due to several factors. Date of planting is probably the most important. Both plots were seeded on 10 October which is 25 days past the optimum planting date as recommended by Calhoun and Crane (7). Seeding was delayed due to abnormal amounts of rain in September (9.09 cm, a + 5.77 cm deviation from normal)(2) which rendered proper seedbed preparation impossible until the first week of October. Dependence on the weather is one of the inherent problems of fall seeded *P. bracteatum* in western Oregon.

No significant differences in plant survival or relative vigor were found between the transplants or the greenhouse grown cuttings at any time during the period of establishment (Tables 2 and 3). Subsequent measurements, however, showed consistent vigor and a high rate of plant survival (Tables 6 and 7).

Table 2. Relative vigor ratings of *P. bracteatum* plants in establishment treatments planted in the fall of 1977.

Establishment Treatment	Date of Vigor Rating 3/3/78	5/10/78	10/18/78	4/13/79
	Vigor ratings[1]			
Peat pellet transplants	3.65[2] NS	5.25 NS	6.25 NS	4.75 NS
$S_{\overline{X}}$	1.45	0.50	3.59	1.50
Greenhouse grown cuttings	6.28	5.50	7.75	7.70
$S_{\overline{X}}$	1.28	1.91	1.50	2.16

[1]Rating of relative plant vigor based on a 1-10 scale. The plant or plants in each plot that appeared most vigorous in terms of number of leaves, color, turgidity of leaves, and plant height were assigned a 10 and the other plants in each plot rated by comparison.

[2]Means of four replications.

[NS]Not significant at the 5% level of probability.

Table 3. Number of *P. bracteatum* plants from the fall 1977 planting surviving at various dates.

Establishment Treatments	Date of Stand Count 3/3/78	5/10/78	10/18/78	7/13/79
	Number of plants[1]			
Peat pellet transplants	5.25[2] NS	4.50 NS	5.0 NS	4.0 NS
$S_{\overline{X}}$	2.22	2.52	3.26	3.74
Greenhouse grown cuttings	8.25	7.75	8.75	7.75
$S_{\overline{X}}$	2.06	2.22	2.99	2.22

[1]Based on a maximum of ten plants per 3.1 by .60 meter plot.

[2]Means of four replications.

[NS]Not significant at the 5% level of probability.

Fall 1978. All five treatments in the Fall 1978 planting had observable differences in both plant survival and relative vigor. However, the stands were so poor that this planting was terminated in May 1979 (Tables 4 and 5). The poor stands resulted from an abnormal amount of precipitation in September of 1978 (8.64 cm total rainfall, a + 5.31 cm deviation from normal)(2), which caused a crust to form and prevented normal germination and growth of both direct seeded treatments. Unusually cold and dry winter months resulted in the demise of the transplants, greenhouse grown cuttings, and directly planted cuttings. The mean deviation from the normal temperatures for the months of November through February was 2.6°C lower than normal (2). The mean deviation from the normal amount of precipitation for the period October 1978 to January 1979 was 8.18 cm below the norm (2).

Spring 1978. Throughout the period of establishment, significant differences in the number of plants surviving and the relative vigor were observed between treatments in the Spring 1978 planting (Tables 6 and 7). In this planting the greenhouse grown cuttings failed to root in sufficient quantity to warrant transplanting for two distinct reasons. The stage of growth was the most important. In my opinion, during the active vegetative growth that occurs in the spring, carbohydrates were translocated out of the roots and to the actively growing meristem. Thus, adventitious root production did not occur. In addition, many of the cuttings rotted. Thus, further comparisons were made only among the directly seeded treatments, the peat pellet transplants and the directly planted cuttings.

Table 4. Relative vigor ratings of *P. bracteatum* plants in establishment treatments planted in the fall of 1978.

Establishment Treatment	Date of Vigor Rating 4/13/79	5/5/79
	Vigor rating[1]	
Direct seeded	1.00[2,3]	1.00
$S_{\overline{X}}$	0.82	0.82
Direct seeded under charcoal	1.25	3.50
$S_{\overline{X}}$	0.50	3.51
Peat pellet transplants	1.00	0.75
$S_{\overline{X}}$	0.82	1.50
Greenhouse grown cuttings	0.75	0.50
$S_{\overline{X}}$	0.96	1.00
Directly planted cuttings	1.00	0.75
$S_{\overline{X}}$	0.82	1.50

[1]Rating of relative plant vigor based on a 1-10 scale. The plant or plants in each plot that appeared most vigorous in terms of number of leaves, color, turgidity of leaves, and plant height, were assigned a 10 and the other plants rated by comparison.

[2]Means of four replications.

[3]No statistical analysis of this planting was made due to missing plots caused by adverse weather conditions.

Table 5. Number of *P. bracteatum* plants from the fall 1978 planting surviving at various dates.

Establishment treatments	Date of Stand Count 4/13/79	5/5/79
	Number of plants[1]	
Direct seeded	4.00[2,3]	2.25
$S_{\bar{x}}$	1.25	2.63
Direct seeded under charcoal	1.25	1.00
$S_{\bar{x}}$	0.50	0.82
Peat pellet transplants	2.25	0.75
$S_{\bar{x}}$	3.20	1.50
Greenhouse grown cuttings	1.00	0.75
$S_{\bar{x}}$	1.41	1.50
Directly planted cuttings	1.25	0.25
$S_{\bar{x}}$	0.96	0.50

[1]Based on a maximum of ten plants per 3.1 by .60 meter plot.

[2]Means of four replications.

[3]No statistical analysis of this planting was made due to missing plots caused by adverse weather conditions.

Table 6. Relative vigor ratings of *P. bracteatum* in establishment treatments planted in the spring of 1978.

Establishment Treatment	Date of Vigor Rating 6/30/78		10/18/78		4/13/79
			Vigor ratings[1]		
Direct seeded	7.25* [2,3]	a	8.00**	ab	6.00 NS
$S_{\bar{x}}$	1.26		1.41		2.00
Direct seeded under charcoal	8.75	a	8.25	ab	6.75
$S_{\bar{x}}$	4.43		0.50		2.75
Peat pellet transplants	7.75	a	9.75	a	5.00
$S_{\bar{x}}$	0.50		0.50		1.63
Directly planted cuttings	0.00	b	7.00	b	5.75
$S_{\bar{x}}$	0.00		0.82		1.71

[1] Ratings of relative plant vigor based on a 1-10 scale. The plant or plants in each plot that appeared most vigorous in terms of number of leaves, color, turgidity of leaves, and plant height, were assigned a 10 and the other plants rated by comparison.

[2] Means of four replications.

[3] Means within columns followed by the same letter(s) are not significantly different from each other at the indicated (*,**) level of probability according to Duncan's multiple range test (18).

*, ** Significant at the 5% and 1% levels of probability, respectively.

NS Not significant at the 5% level of probability.

Table 7. Number of *P. bracteatum* plants in the spring 1978 planting surviving at various dates.

Establishment Treatments	Date of Stand Count		
	6/30/78[1]	10/18/78	7/13/79
		Number of plants[2]	
Direct seeded	20.25**[3,4] a	10.00** a	9.50** a
$S_{\bar{x}}$	3.10	0.00	1.00
Direct seeded under charcoal	8.25 b	9.25 a	7.25 a
$S_{\bar{x}}$	5.10	0.58	0.96
Peat pellet transplants	11.00 b	10.00 a	10.00 a
$S_{\bar{x}}$	0.71	0.00	0.00
Directly planted cuttings	0.00 c	6.00 b	2.75 b
$S_{\bar{x}}$	0.00	2.16	1.71

[1]Stand counts made before thinning.

[2]Based on a maximum of ten plants per 3.1 by .60 meter plot.

[3]Means of four replications.

[4]Means within columns followed by the same letter(s) are not significantly different from each other at the indicated (**) level of probability according to Duncan's multiple range test (18).

**Significant at the 1% level of probability.

The plots directly seeded under charcoal produced the poorest stands. This was contrary to the findings reported by Calhoun and Crane (7). However, these seemingly poor stands survived throughout the entire experimental period and went on to produce yields which were not significantly different than the highest yielding plot in the Spring 1978 planting. This is the first indication that relative plant vigor may not be a good measurement of stand establishment.

No growth was observed in the directly planted cuttings until 18 October, which was after the end of the summer dormancy period. It appears that the environmental conditions in the field were more conducive to establishment of directly planted cuttings than greenhouse grown cuttings. No measurements made in this experiment could offer an explanation as to why.

Growth and Development

Growth and development of *P. bracteatum* seedlings and propagules was evaluated by measurement of the relative vigor and plant survival of each plot.

Fall 1977. In the Fall 1977 planting, no significant differences were detected between methods of establishment (Tables 2 and 3). Lack of variation in the measurement of vigor indicates that this may not be a good method of assessing differences between methods of propagation. However, stand counts, while not significant in this case, may be useful in estimating yield potential.

Fall 1978. Statistical analysis of the Fall 1978 planting was impossible due to an excess of missing plots caused by adverse weather conditions. However, it was observed that the plants in the plots seeded under charcoal were growing more vigorously than any other plots that survived. It was believed that this apparent vigor was due to the lack of weed competition.

Spring 1978. Data collected on 30 June 1978 from the Spring 1978 planted materials showed significant differences in relative vigor but not in number of plants surviving (Tables 6 and 7). The direct seeded plots were found to be less vigorous than those seeded under charcoal or the transplants, suggesting that early weed competition may have been a factor. The measurements made on 18 October showed highly significant differences in the relative vigor of the treatments. However, only the directly planted cuttings were found to be significantly lower than the rest. This same relationship was true for the number of plants surviving at this date (Tables 6 and 7). The pre-bloom vigor rating made on 13 April 1979 showed no significant differences between methods of establishment. At the time of harvest on 13 July 1979, the stands were counted. Only the treatment with directly planted cuttings was found to have a significantly lower stand count.

Yield Components

Fall 1977. The greenhouse grown cuttings in the Fall 1977 planting produced yields of 443.3 kilograms per hectare of dry capsules[1] (Table 8). This harvest occurred 22 months after the plants had been established. The yields in this plot were well below the

[1]Capsule harvest included 15 cm of attached peduncle.

Table 8. Yield components and estimated yields per hectare of *P. bracteatum* at the time of first economic harvest after establishment.

Plot Treatment	Plant Age At Harvest	Total Capsule Number	Capsules Per Plant	Total Capsule Weight (g)	Estimated Yield (Kilograms Per Hectare)
Fall 1977					
Peat pellet transplants	22 mos.	10.00** [1]	2.64**	36.33*	195.2*
Greenhouse grown cuttings	22 mos.	29.00	3.83	82.50	443.3
Spring 1978					
Direct seeded	14 mos.	10.25 [2] ** b	1.08 NS	23.75** ab	127.6** ab
Direct seeded under charcoal	14 mos.	9.00 b	1.26	27.75 ab	149.1 ab
Peat pellet transplants	14 mos.	22.75 a	2.28	55.75 a	299.6 a
Directly planted cuttings	14 mos.	2.50 b	1.26	5.00 b	26.9 b

[1] All figures given are means of four replications.

[2] Means within columns followed by the same letter(s) are not significantly different from each other at the indicated level of probability (*,**) according to Duncan's multiple range test (18).

*,** Significant at the 5% and 1% level of probability, respectively.

NS Not significant at the 5% level of probability.

estimated potential yields (1000 kilograms per hectare)(12) in western Oregon for plants 36 months old or older. However, the yields were believed to be sufficient for an economic harvest. The greenhouse grown cuttings were also significantly more productive than the seedling transplants in measurement of total capsule number, total capsule weight, and mean number of capsules per plant. There were no detectable differences in mean weight per capsule or seed weight (Tables 9-13). The differences between the greenhouse grown cuttings and seedling transplants can be explained by the age of the plant material utilized in this experiment. At the time of field planting, the greenhouse grown cuttings were buds of 18-month-old plants, as compared to the seedling transplants which were two months old. The carbohydrates stored in the root wedges used in this experiment seemed to result in rapid vegetative development and subsequently more vigorous reproductive growth. This hypothesis seems to be supported by capsule yields of 443.3 kilograms per hectare for the greenhouse grown cuttings and of 195.2 kilograms per hectare for the seedling transplants (Table 8).

Spring 1978. The method of establishment that resulted in the highest yields in the Spring 1978 planting was the seedling transplants. Yields of 299.6 kilograms per hectare dry capsules and 15 cm of peduncle were obtained from 14 month old plants (Table 8). However, this figure was not statistically different from the yields of 127.6 and 149.1 kilograms per hectare obtained from the direct seeding and direct seeding under charcoal treatments, respectively. The coefficient of variation for this data

Table 9. Total capsule number of *P. bracteatum* for two dates of planting at time of harvest on July 13, 1979.

Establishment Treatments	Date of Planting: Fall 1977	Date of Planting: Spring 1978	
	Number of capsules per plot[1]		
Direct seeded	---	10.25** [3]	b
$S_{\bar{x}}$		1.89	
Direct seeded under charcoal	---	9.00	b
$S_{\bar{x}}$		3.83	
Peat pellet transplants	10.00** [2]	22.75	a
$S_{\bar{x}}$	8.60	7.45	
Greenhouse grown cuttings	29.00	---	
$S_{\bar{x}}$	8.45		
Directly planted cuttings	---	2.50	b
$S_{\bar{x}}$		1.29	

[1]Plots are 3.1 m by 0.60 m.

[2]Means of four replications.

[3]Means within columns followed by the same letter(s) are not significantly different from each other at the indicated level of probability (**) according to Duncan's multiple range test (18).

**Significant at the 1% level of probability.

Table 10. Total capsule weight of *P. bracteatum* for two dates of planting at time of harvest on July 13, 1979.

Establishment Treatments	Date of Planting: Fall 1977	Date of Planting: Spring 1978	
	Total weight of capsules (g)[1]		
Direct seeding	---	23.75** [3]	ab
$S_{\bar{x}}$		7.68	
Direct seeding under charcoal	---	27.75	ab
$S_{\bar{x}}$		13.23	
Peat pellet transplants	36.33* [2]	55.75	a
$S_{\bar{x}}$	24.23	21.11	
Greenhouse grown cuttings	82.50	---	
$S_{\bar{x}}$	28.66		
Directly planted cuttings		5.00	b
$S_{\bar{x}}$		3.37	

[1] Includes 15 cm of peduncle.

[2] Means of four replications.

[3] Means with columns followed by the same letter(s) are not significantly different from each other at the indicated level of probability according to Duncan's multiple range test (18).

*,** Significant at the 5% and 1% level of probability, respectively.

Table 11. Mean number of capsules per plant of *P. bracteatum* for two dates of planting at time of harvest on July 13, 1979.

Establishment Treatments	Date of Planting	
	Fall 1977	Spring 1978
	Number of capsules per plant	
Direct seeding	---	1.08 NS
$S_{\bar{x}}$		0.17
Direct seeding under charcoal	---	1.26
$S_{\bar{x}}$		0.53
Peat pellet transplants	2.64** [1]	2.28
$S_{\bar{x}}$	1.41	0.74
Greenhouse grown cuttings	3.83	---
$S_{\bar{x}}$	0.95	
Directly planted cuttings		1.26
$S_{\bar{x}}$		0.76

[1] Means of four replications.

** Significant at the 1% level of probability.

NS Not significant at the 5% level of probability.

Table 12. Mean weight per capsule in grams of *P. bracteatum* for two dates of planting at time of harvest on July 13, 1979.

Establishment Treatments	Date of Planting	
	Fall 1977	Spring 1978
	Weight per capsule (g)[1]	
Direct seeding	---	2.29* [3] b
$S_{\bar{x}}$		0.38
Direct seeding under charcoal	---	3.04 a
$S_{\bar{x}}$		0.28
Peat pellet transplants	2.02[2] NS	2.43 ab
$S_{\bar{x}}$	1.35	0.29
Greenhouse grown cuttings	2.82	---
$S_{\bar{x}}$	0.30	
Directly planted cuttings	---	1.81 b
$S_{\bar{x}}$		0.55

[1]Includes 15 cm of peduncle.

[2]Mean of four replications.

[3]Means within columns followed by the same letter(s) are not significantly different from each other at the indicated level of probability (*) when according to Duncan's multiple range test (18).

*Significant at the 5% level of probability.

NS Not significant at the 5% level of probability.

Table 13. Seed weight in grams of *P. bracteatum* for two dates of planting at time of harvest on July 13, 1979.

Establishment Treatments	Date of Planting	
	Fall 1977	Spring 1978
	Seed weight (g)	
Direct seeding	---	8.00** [2] ab
$S_{\overline{X}}$		3.74
Direct seeding under charcoal	---	3.80 b
$S_{\overline{X}}$		4.50
Peat pellet transplants	5.33[1] NS	18.30 a
$S_{\overline{X}}$	3.92	7.41
Greenhouse grown cuttings	16.25	---
$S_{\overline{X}}$	6.65	
Directly planted cuttings	---	1.5 b
$S_{\overline{X}}$		1.00

[1]Means of four replications.

[2]Means within columns followed by the same letter(s) are not significantly different from each other at the indicated level of probability (**) according to Duncan's multiple range test (18).

**Significant at the 1% level of probability.

NSNot significant at the 5% level of probability.

was 51.88% (Appendix Table 8). The seedling transplants were, however, significantly higher than the other methods of establishment in total capsule number per plot and seed weight (Tables 9 and 13). The seedling transplants did not differ significantly from the plots seeded under charcoal in total capsule weight (Table 10) and mean weight per capsule (Table 12) nor from the directly seeded plots in total capsule weight (Table 10), mean weight per capsule (Table 12), and seed weight (Table 13). It must be noted that the directly seeded, directly seeded under charcoal, and seedling transplants did not differ statistically in the number of plants per plot at the time of harvest (Table 7). Thus the data for the Spring 1978 planting show no difference in yield potential between either of the direct seeded treatments or the seedling transplants.

Thebaine. While no mention was made in this thesis of thebaine percentage as it relates to the method of establishment, we assumed that the utilization of identical germplasm would insure a constant thebaine percentage between treatments.

Establishment Costs

The goal of this experiment, as previously stated, was to compare the productivity and economics of five methods of establishment of *Papaver bracteatum* in western Oregon. In order to make these comparisons, each method of establishment must have a cost assigned to each step in the operation. Once these costs of production have been estimated, comparisons of the different methods can be made and decisions concerning the most economical method discussed.

The approximate costs per hectare of the steps in establishment of *P. bracteatum* are listed below (Tables 14 and 15). These figures have been estimated from Oregon State University Cooperative Extension Service reports and the experience of workers in the field (3, 16). The establishment costs of *P. bracteatum*, which is a perennial crop, would be amortized over the life of the stand (Table 16). Modest economic yields in the first year could also offset the initial costs.

Assuming the costs of establishment for any of the methods are constant for the initial land preparation and certain other operations (Table 14), the differences in costs of one method of establishment versus another lie in the differences in the techniques of each method. Table 15 summarizes the steps required for each method of establishment and the cost per acre of each step (3, 16).

If we assume that all the costs will be equal except those incurred at the time the stand is established, we can estimate establishment costs per hectare per year based on the life of the stand (Table 16).

The establishment costs calculated for each method utilized in this experiment range from $290.72 per hectare for fall direct seeding to $3650.72 per hectare for spring planted peat pellet transplants. In order to decide which method of establishment would be appropriate for this area, both the costs and associated production problems have to be considered. Factors such as weed competition, variability and vulnerability of *P. bracteatum* seedlings

Table 14. Estimated initial costs of establishment of *P. bracteatum* in western Oregon.

Operation	Cost Per Hectare ($)	
Land preparation	45.45	
Fertility (10.00 per application)	20.00	
Preplant 336 kilograms/hectare 16-20-0		68.54
Fall 56 kilograms/hectare $(NH_4)_2SO_4$		7.98
Herbicide (3.71 per application)	3.71	
Diuron 1.8 kilograms/hectare a.i.		13.09
Harvest	61.75	
TOTAL	200.72	

Table 15. Approximate per hectare costs of five methods of establishment for two times of planting of *Papaver bracteatum* in Corvallis, Oregon.

Method of Establishment Operation	Per Hectare Costs Spring	 Fall
Direct seeding		
Seed drill	30.00	30.00
Irrigation (19.76 per irrigation)	200.00	60.00
Total	230.00	90.00
Direct seeding under charcoal		
Seeding - includes equipment, charcoal banding, and initial herbicide application	75.00	75.00
Irrigation	200.00	60.00
Total	275.00	135.00
Transplants in peat pellets		
Peat pellets (55,000 per hectare)	2200.00	2200.00
Greenhouse costs	550.00	550.00
Transplanting	500.00	500.00
Irrigation	200.00	60.00
Total	3450.00	3310.00
Greenhouse grown cutting		
Digging and cutting crowns	625.00	625.00
Greenhouse costs	500.00	500.00
Transplanting	500.00	500.00
Irrigation	200.00	60.00
Total	1825.00	1685.00
Directly planted cuttings		
Digging and cutting crowns	500.00	500.00
Transplanting	500.00	500.00
Irrigation	200.00	60.00
Total	1200.00	1060.00

Table 16. Approximate per hectare costs of five methods of establishment for two times of planting of *Papaver bracteatum* averaged over the life of the stand.

Method of Establishment	Average Per Hectare Costs ($) After 1st Year	5th Year	15th Year
Direct seeding			
Fall	290.72	58.14	19.38
Spring	430.72	86.14	28.71
Direct seeding under charcoal			
Fall	335.72	67.14	22.38
Spring	475.72	95.14	31.71
Transplants in peat pellets			
Fall	3510.72	702.14	234.05
Spring	3650.72	730.14	243.38
Greenhouse grown cuttings			
Fall	1885.72	377.14	125.71
Directly planted cuttings			
Fall	1260.72	252.14	84.05

as well as other potential stand losses could be important in modifying results from this type of experiment.

While direct seeding may be the least expensive method of establishment at $28.71 per hectare for spring seeded poppies over a projected 15 year stand, the disadvantages of this method may outweigh its benefits. Direct seeding without weed control results in poor stands (7). In order to replant, the initial costs of planting will increase. There is also the danger of stand losses due to inclement weather, which may result in a complete loss of one season of growth (16).

Direct seeding under charcoal is initially more expensive at $31.71 per hectare for fall seeded poppies than direct seeding. It usually results in better stands due to the associated herbicide application for weed control. However, as with the direct seeding, problems with stand losses due to weather may still be a factor. Thus the initial costs may be increased, or at worst result in a complete loss of the stand.

The use of transplants is favored by industry (16). Vigorous, healthy seedlings can be raised in the greenhouse and transplanted to the field with an 80 to 90 percent average survival rate (16). The initial costs of transplanting, utilizing peat pellets as a planting medium, are $3510.72 and $3650.72 per hectare for fall and spring established seedlings, respectively. This initial cost per acre is high but will decrease with the size of the operation. An additional benefit is that the entire planting operation can be mechanized (16). The resulting stand is uniform in plant population and seedling vigor (16). Filling in any gaps or losses in the stand is usually minimal and may be done at any time utilizing the same equipment (16).

Work done by a leading pharmaceutical company indicated that the use of transplants was the most expensive method of establishment; but costs could be cut drastically by using transplants produced in reusable flats rather than in small individual pots or peat pellets (16). They estimated costs of production of transplants under these circumstances would be $2650.72 per hectare or $1000.00 less than the figure utilizing peat pellets. Thus while transplants seem to be the best method of establishment of *P. bracteatum*, additional screening of methods of transplant production would have to be done in order to determine the most economical method.

The use of root crown cuttings for anything but experimental purposes seems impractical. In addition to the planting operation, the roots must be grown for several years, dug and divided before planting. It appears from the above data that per hectare costs of $1885.72 for fall established greenhouse grown cuttings is less expensive than transplanting. This figure does not take into account the costs of the operations listed above which were found to be difficult to approximate and thus were not included in this analysis. In addition, in most cases the uniformity of the growth and the survival of these propagules is poor (16).

V. SUMMARY AND CONCLUSIONS

Recently, a worldwide shortage of opium was predicted (20, 21). It was thought that additional sources of opium for conversion into codeine and other valuable pharmaceuticals would be required by the medical industry for use as an antitussive and analgesic (20, 21). The opium poppy, *Papaver somniferum*, has long been the only source of codeine, as well as heroin and other drugs of abuse (26). In order to evaluate alternative sources of these licit compounds, studies were undertaken worldwide to evaluate potential new plant sources. One species native to Iran, *Papaver bracteatum*, proved to be a potential alternate source of codeine (20, 21, 25, 26, 27, 29).

The U.S.D.A., in conjunction with The United Nations Secretariat, Division of Narcotic Drugs, began domestic studies with *P. bracteatum*. Research was begun in 1975 at Oregon State University in Corvallis, Oregon to study the agronomic characteristics and production practices of this crop in western Oregon.

As part of this program, an experiment was initiated in 1977 to test several methods of establishment of *P. bracteatum* in order to evaluate its growth, development and yield components. An additional goal was to outline and analyze the relative costs of these methods and to describe how they could affect the choice of method of establishment in this area.

Five methods of establishment were examined in this study including: direct seeding, direct seeding under charcoal, seedling transplants, greenhouse grown root crown cuttings, and directly planted root crown cuttings. These methods were tested in the fall of 1977 and 1978, and the spring of 1978 utilizing a randomized complete block experimental design with four replications.

Measurements of relative vigor and stand survival were made. Relative vigor was not found to be a useful measurement of differences between methods of establishment. This result was due to the variability in vigor among plants and treatments. Stand survival seems to be an accurate method of gauging yield potential in mature stands.

The best stands and highest economic yields were obtained from 22 month old, fall planted, greenhouse grown root crown cuttings. Similar stands and yields were obtained from 14 month old, spring planted, seedling transplants and from plants established by seed under activated charcoal with the accompanying application of an appropriate herbicide.

A simple cost analysis indicated that the most economical method of establishment was direct seeding in the fall. However, this does not take into account additional production costs which may be incurred such as weed control or the replanting of the stand due to the variability and vulnerability of *P. bracteatum* seedlings. Production costs for each method of establishment must be considered for the projected economic life of the stand of 15 years, when estimating the potential economic returns.

From the data presented in this thesis, it seems that *P. bracteatum* has the agronomic potential to be commercially grown in the Willamette Valley of western Oregon. However, a thorough cost analysis and consideration of any additional constraints at the time of stand establishment would have to be taken into account in the selection of the best method of establishment of *P. bracteatum.*

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APPENDIX

Appendix Table 1. Weather Summary For Crop Year 1977-78, Corvallis, Oregon (2).

Air Temperatures

Year	Month	Mean Max.	Mean Min.	Mean	Dev. Norm.	High	Low
1977	September	70.8	47.8	59.3	-2.7	87	40
	October	64.1	43.8	54.0	+0.8	71	36
	November	51.2	37.7	44.5	-0.8	60	22
	December	48.9	38.8	43.9	+2.9	61	26
1978	January	46.6	37.2	41.9	+3.1	54	27
	February	51.7	40.0	45.9	+2.8	62	30
	March	59.2	40.4	49.8	+4.3	76	29
	April	57.8	42.2	50.0	-0.1	75	32
	May	63.6	44.7	54.1	-1.6	85	31
	June	75.0	51.1	63.1	+2.1	92	44
	July	80.7	52.7	66.7	+0.8	99	43
	August	80.0	53.2	66.6	+0.8	103	45

High: 103 August 9 Low: 22 November 20

Precipitation and Sky Conditions

Year	Month	Rain	Dev. Norm.	Snow	Clear	Pt. Cloudy	Cloudy	Rain
1977	September	3.58	+ 2.27	0	10	7	13	15
	October	2.58	- 1.20	0	11	6	14	12
	November	8.11	+ 2.07	3.3	5	9	16	21
	December	11.03	+ 4.20	0	4	3	24	24
1978	January	7.34	+ 0.28	0	2	5	24	25
	February	4.28	- 0.35	0	2	5	21	19
	March	2.15	- 2.05	0	5	6	20	12
	April	4.94	+ 2.89	0	8	4	18	22
	May	3.61	+ 1.84	0	9	8	14	18
	June	0.94	- 0.21	0	9	9	12	8
	July	0.29	- 0.04	0	13	7	11	3
	August	2.34	+ 1.79	0	11	7	13	13
TOTAL		51.19	+11.49	3.3	89	76	200	192

Appendix Table 2. Weather Summary For Crop Year 1978-79, Corvallis, Oregon (2).

Air Temperatures

Year	Month	Mean Max.	Mean Min.	Mean	Dev. Norm.	High	Low
1978	September	69.9	49.6	59.8	-2.2	80	40
	October	67.1	40.4	53.8	+0.6	81	28
	November	48.9	30.9	39.9	-5.4	63	18
	December	43.0	29.6	36.3	-4.7	53	14
1979	January	37.5	25.7	31.6	-7.2	53	12
	February	47.1	36.0	41.6	-1.5	56	13
	March	58.3	38.6	48.5	+3.0	70	32
	April	59.2	41.3	50.3	+0.2	77	33
	May	68.0	43.1	55.6	-0.1	85	33
	June	75.7	46.4	61.1	+0.1	91	36
	July	82.0	50.9	66.5	+0.6	102	43
	August	78.8	50.8	64.8	-1.0	93	44

High: 102 July 17 Low: 12 January 1

Precipitation and Sky Conditions

Year	Month	Rain	Dev. Norm.	Snow	Clear	Pt. Cloudy	Cloudy	Rainy
1978	September	3.40	+2.09	0	6	8	16	14
	October	0.98	-2.80	0	15	6	10	5
	November	3.14	-2.90	1.0	11	3	16	12
	December	4.23	-2.60	1.9	5	3	23	18
1979	January	2.57	-4.49	.8	9	6	16	14
	February	8.35	+3.72	.3	2	4	22	24
	March	2.89	-1.31	0	11	8	12	17
	April	2.93	+0.88	0	5	10	15	19
	May	2.11	+0.34	0	13	8	10	9
	June	0.38	-0.77	0	19	1	10	2
	July	0.43	+0.10	0	20	5	6	4
	August	2.67	+2.12	0	13	2	16	8
TOTAL		34.08	-5.62	3.0	129	64	172	146

Appendix Table 3. Analysis of variance for relative vigor ratings of *P. bracteatum* in establishment treatments planted in the fall of 1977.

Date	Source	df	MS	F
March 3, 1978	Replication	3	.21	.05 NS
	Methods	1	13.79	3.54 NS
	Error	3	11.69	
	Total	7	---	
	C.V. = 29.89%			
May 10, 1978	Replication	3	2.12	1.18 NS
	Methods	1	.12	.06 NS
	Error	3	1.79	
	Total	7	---	
	C.V. = 24.89%			
October 18, 1978	Replication	3	8.33	1.22 NS
	Methods	1	4.50	.66 NS
	Error	3	6.83	
	Total	7	---	
	C.V. = 37.33%			
April 13, 1979	Replication	3	3.46	1.00 NS
	Methods	1	10.12	2.92 NS
	Error	3	3.46	
	Total	7	---	
	C.V. = 31.66%			

[NS]Not significant at the 5% level of probability.

Appendix Table 4. Analysis of variance of number of *P. bracteatum* plants in the fall 1977 planting surviving at various dates.

Date	Source	df	MS	F
March 3, 1978	Replication	3	7.0	3.18 NS
	Treatment	1	18.0	8.18 NS
	Error	3	2.2	
	Total	7		
	C.V. = 21.97%			
May 10, 1978	Replication	3	7.79	2.25 NS
	Treatment	1	21.13	6.11 NS
	Error	3	3.46	
	Total	7		
	C.V. = 30.37%			
October 18, 1978	Replication	3	12.46	1.75 NS
	Treatment	1	28.12	3.94 NS
	Error	3	7.13	
	Total	7		
	C.V. = 38.84%			
July 13, 1979	Replication	3	9.12	2.91 NS
	Treatment	1	15.12	4.83 NS
	Error	3	3.13	
	Total	7		
	C.V. = 30.11%			

^{NS}Not significant at the 5% level of probability.

Appendix Table 5. Analysis of variance of relative vigor ratings of *P. bracteatum* in establishment treatments planted in the spring of 1978.

Date	Source	df	MS	F
June 30, 1978	Replication	3	2.08	6.30*
	Treatment	3	2.34	7.09*
	Error	9	.33	
	Total	15		
	C.V. = 8.01%			
October 18, 1978	Replication	3	1.17	1.75 NS
	Treatment	3	5.17	7.72**
	Error	9	.67	
	Total	15		
	C.V. = 8.12%			
April 13, 1979	Replication	3	1.08	.34 NS
	Treatment	3	2.08	.66 NS
	Error	9	3.14	
	Total	15		
	C.V. = 30.16%			

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

NS Not significant at the 5% level of probability.

Appendix Table 6. Analysis of variance of number of *P. bracteatum* plants in the spring 1978 planting surviving at various dates.

Date	Source	df	MS	F
June 30, 1978	Replication	3	9.22	2.53 NS
	Treatment	3	111.09	30.52**
	Error	9	3.64	
	Total	15		
	C.V. = 14.49%			
October 18, 1978	Replication	3	1.75	1.47 NS
	Treatment	3	14.58	12.25**
	Error	9	1.19	
	Total	15		
	C.V. = 13.41%			
July 13, 1979	Replication	3	.83	.58 NS
	Treatment	3	43.42	30.15**
	Error	9	1.44	
	Total	15		
	C.V. = 16.27%			

**Significant at the 1% level of probability.

NS Not significant at the 5% level of probability.

Appendix Table 7. Analysis of variance of total capsule number per plot of *P. bracteatum* at time of harvest on July 13, 1979.

Date	Source	df	MS	F
Fall 1977	Replication	3	122.79	7.61 NS
	Treatment	1	703.12	43.59**
	Error	3	16.13	
	Total	7		
	C.V. = 20.60%			
	$L.S.D._{.01}$ = 16.59			
Spring 1978	Replication	3	10.25	.49 NS
	Treatment	3	284.00	13.52**
	Error	9	21.00	
	Total	15		
	C.V. = 41.19%			

**Significant at the 1% level of probability.

NS Not significant at the 5% level of probability.

Appendix Table 8. Analysis of variance of total capsule weight per plot of *P. bracteatum* at time of harvest on July 13, 1979.

Date	Source	df	MS	F
Fall 1977	Replication	3	894.12	4.43 NS
	Treatment	1	4656.12	23.07*
	Error	3	201.79	
	Total	7		
	C.V. = 24.33%			
	L.S.D.$_{.05}$ = 31.96			
Spring 1978	Replication	3	33.73	.16 NS
	Treatment	3	1756.23	8.28**
	Error	9	212.00	
	Total	15		
	C.V. = 51.88%			

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

NS Not significant at the 5% level of probability.

Appendix Table 9. Analysis of variance of mean number of capsules per plant of *P. bracteatum* at time of harvest on July 13, 1979.

Date	Source	df	MS	F
Fall 1977	Replication	3	1.68	129.46**
	Treatment	1	4.88	375.38**
	Error	3	.01	
	Total	7		
	C.V. = 3.74%			
	L.S.D.$_{.01}$ = 4.13			
Spring 1978	Replication	3	.47	1.47 NS
	Treatment	3	1.18	3.69 NS
	Error	9	.32	
	Total	15		
	C.V. = 38.51%			

**Significant at the 1% level of probability.

NSNot significant at the 5% level of probability.

Appendix Table 10. Analysis of variance of mean weight per capsule in grams for two dates of planting at the time of harvest on July 13, 1979.

Date	Source	df	MS	F
Fall 1977	Replication	3	.097	4.85 NS
	Treatment	1	.070	3.50 NS
	Error	3	.020	
	Total	7		
	C.V. = 5.20%			
Spring 1978	Replication	3	.14	.88 NS
	Treatment	3	1.03	6.44*
	Error	9	.16	
	Total	15		
	C.V. = 16.72%			

*Significant at the 5% level of probability.

NS Not significant at the 5% level of probability.

Appendix Table 11. Analysis of variance of seed weight in grams of *P. bracteatum* for two dates of planting at time of harvest on July 13, 1979.

Date	Source	df	MS	F
Fall 1977	Replication	3	48.83	5.83 NS
	Treatment	1	288.00	34.70**
	Error	3	8.30	
	Total	7		
	C.V. = 28.11%			
	$L.S.D._{.01}$ = 11.90			
Spring 1978	Replication	3	2.08	.07 NS
	Treatment	3	210.42	7.16**
	Error	9	29.36	
	Total	15		
	C.V. = 70.00%			

**Significant at the 1% level of probability.

NS Not significant at the 5% level of probability.