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Title: The Effect of Harvest Date and Pre-Storage Drying Methods on Capsule Thebaine Yield, Seed Oil Yield and Seed Germination of Two Accessions of Papaver bracteatum Lindl.

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A field study was conducted in 1978 and 1979 at the Hyslop Crop Science Field Laboratory near Corvallis, Oregon, to determine the optimum capsule harvest date of Papaver bracteatum Lind. for thebaine yield and oil yield, while maintaining an acceptable percentage of seed germination. Accessions PI 383309 and PI 381607 were chosen for this study because of their superior yield characteristics. The effects of pre-storage drying of harvested plant materials on the yields and seed germination were studied in the second year of the experiment.

Both accessions responded similarly to all treatments. The effects of harvest dates on the yield components and seed germination were comparable in the two years of the study except for the seed yield. The difference for the seed yield was due to earlier capsule maturity in 1979 that resulted in earlier seed shattering in that year. Drying of the harvested plant materials in a dryer immediately after harvest did not significantly affect the oil and thebaine yields or the percentage of seed germination.

Although the data for the thebaine concentration of the capsules in 1978 were of questionable accuracy, capsule thebaine yield was not significantly different for the harvest dates later than four weeks

after petal opening. Seed oil yield was not significantly affected by the harvest dates in 1978. However, in 1979, seed oil yield for the harvests later than seven weeks after petal opening were significantly lower than that on the earlier harvest dates. While seed oil content was very stable, seed shattering was responsible for the decline of seed oil yield on the later harvest dates in both years of the study. Seed shattering was more pronounced in the second year of the study when plants produced larger capsules and more seeds.

Seed germination was not significantly affected by the harvest dates. Seeds were found to be viable four weeks after petal opening, or earlier, although they continued to develop in the capsules for two to three weeks after that date.

Seven weeks after petal opening was found to be the optimum capsule harvest date under the climatic conditions of the experimental site. Thebaine yield of approximately eight kilograms per hectare was calculated for the capsules harvested on that date. Forty-five kilograms of oil were obtained from the seeds of capsules harvested seven weeks after petal opening in 1978. This yield was significantly higher in 1979 when it exceeded sixty-five kilograms of oil per hectare.

Generally, total seed oil yield and capsule weight of both accessions increased, while capsule thebaine concentration tended to decrease as plants increased from two to three years of age.

THE EFFECT OF HARVEST DATE AND PRE-STORAGE DRYING METHODS ON CAPSULE THEBAINE YIELD, SEED OIL YIELD, AND SEED GERMINATION OF TWO ACCESSIONS OF *PAPAVER BRACTEATUM* LINDL.

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IN DEDICATION TO

My parents for their sacrifices

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

THE EFFECT OF HARVEST DATE AND PRE-STORAGE DRYING METHODS ON CAPSULE THEBAINE YIELD, SEED OIL YIELD, AND SEED GERMINATION OF TWO ACCESSIONS OF *PAPAVER BRACTEATUM* LINDL.

INTRODUCTION

Plants in the family Papaveraceae have been used as a source of medicinal alkaloids for centuries. In this respect, *Papaver somniferum* L., the opium poppy, has received the most attention. Opium, the source for morphine, codeine, thebaine, and other alkaloids essential for licit drug production, is extracted from this plant species. The most dangerous by-product of this poppy is heroin, converted from morphine, which is an illegal and highly addictive drug. However, all of the illicit opium is not used for heroin production. A significant portion of the world's population still consumes the product of opium poppy in forms other than heroin; opium smoking and eating are still very common in many parts of the world. Morphine is also an addictive drug. It is used in the licit market primarily for the production of codeine which is an essential alkaloid for medicinal purposes.

The illicit use of addictive drugs is a serious social hazard. Although many countries, including the United States, have banned entirely the production of the opium poppy, they have not been safe from the illicit traffic of opium and its derivatives. More recently, because of the increase in illicit traffic in opiates, the elimination of opium poppy cultivation has been reviewed in many countries as one means of suppressing the illicit traffic of opium. The ultimate in narcotic and addictive drug control would be the world-wide prohibition of opium production. However, since this substance is the only source of important medicines, such as codeine, there will be a need for opium.

Search for an alternative and adequate substitute for codeine production, other than opium, has been the subject for many studies all over the world. Papaver bracteatum Lindl. has shown the most promising potential as a substitute for the opium poppy. Papaver bracteatum is a perennial species of the Papaveraceae family. It is an opium-free poppy and it does not produce morphine. Instead, its alkaloid contains only thebaine, in high percentage and purity. Thebaine can be easily converted to codeine.

Although the occurrence of thebaine in many species of the Papaveraceae family and other families has been known for many years, it was during the last decade that Papaver bracteatum was introduced as a potential commercial source of thebaine. Since then, the United Nations has become very interested in this plant species as a potential substitute for the opium poppy. Many countries, including the United States, have conducted experiments to investigate agricultural and photochemical aspects of this plant species and to bring this wild plant into commercial cultivation. During this short period of time after the plant introduction as a commercial source for thebaine production, very rapid progress has been made through the sharing of experience by workers from many parts of the world. It is generally believed that this plant can fill the gap between the world's opium supply and its demand for codeine production and also drastically suppress the illicit traffic of opium and its derivatives.

Although thebaine can be found in most organs of this plant, the highest concentration is usually in the roots. However, some workers have demonstrated the potential of the aerial parts for thebaine production. The variation in thebaine content of different strains of this plant species, as well as this variation in relation to the stage of plant development, have also been investigated. However most of these studies have been involved with thebaine concentration in the plant, with little attention given to the total thebaine yield as affected by the date of capsule harvest and capsule storage preconditioning. No uniform method of drying fresh Papaver bracteatum samples has been used in the studies that were reviewed.

The other important purpose of P. bracteatum cultivation, however, is to obtain poppy seed and poppy seed oil for the food industry. Although very little information is available about the seed oil from this plant, it has been reported that qualitatively it is an excellent edible oil similar to opium poppy seed oil. In all previous research on this plant species, seed yield and the potential of P. bracteatum as an oleiferous crop have been neglected. The variation in total thebaine yield and total oil yield in relation to the harvest time of capsules and their storage preconditioning, therefore, needed investigation.

The objectives of this study were to determine the best harvest time of capsules for optimal thebaine yield and oil yield, and also to determine the effects of capsule drying methods on these factors and on the percent seed germination.

LITERATURE REVIEW

I. Some background on opium, its use and abuse.

Since the potential for P. bracteatum to be grown as a commercial crop has been known just for a few years, and because it is believed that P. bracteatum can be substituted for opium poppy (Papaver somniferum), some background about opium poppy could help the reader to better understand the commercial potential of P. bracteatum.

A. Source of Opium

Although all the Papaveraceae species produce alkaloids, very few produce morphine-like substances (8). Opium is produced from several varieties of the species Papaver somniferum (4).

The opium poppy (Papaver somniferum) has been grown by man for thousands of years. In Europe, the plant has been cultivated and used since 1500 B.C. (31). This is an annual species of poppy and is planted mostly in the fall but sometimes in the spring, depending on the climatic conditions of the area (4). About two weeks after the petals fall, the pods (capsules) are lanced by hand and the milky latex-like (opium) oozes out and forms a kind of gum. This gum is collected and is allowed to dry and harden. This substance, that is brown in color by this time, is opium. Opium may be powdered or molded into brick-like forms before marketing and use (4).

B. Opium Production and Market

The opium poppy is grown mostly in Middle Eastern and Far Eastern countries. It is cultivated also in Eastern Europe and scattered parts of North Africa, Australia, Mexico, and South America (4).

However, in some of these countries, it might be grown for purposes other than opium production.

Essentially, there are two separate and distinct major markets for opium; the licit and the illicit markets (4). The licit market is very important to supply the world opium demand for use in pharmaceutical manufacturing. India and Turkey are the two chief suppliers for world opium demand. In 1971, ninety-nine percent of the total world exports came from these two countries (4).

The United States is the number one opium importing country in the world. In 1975, the United States imported approximately 250,000 kilograms of opium. With the average price of about $60 per kilogram, it cost the American importers $15 million (17).

C. Opium and Its Derivatives

Opium is the source for the main alkaloids used in medicine. These alkaloids are morphine, codeine, papaverine, and narcotine, and their derivatives (9).

While opium has been used in medicine for centuries, the pure alkaloids of this substance were not known or utilized until early in the nineteenth century (17). Opium contains more than thirty alkaloids of which the most important ones are those used in medicine (17). The quantities of these alkaloids differ widely for different samples but the generally accepted average percentages are as follows: morphine, 10; codeine, 0.5; thebaine, 0.3; papaverine, 1; narcotine, 6; and narceine, 0.2 (18).

1. Morphine

Morphine is the most important alkaloid of opium from both the licit and illicit standpoint. Morphine is the main source for analgesic (pain-killing), narcotic, and addictive drugs.

Most world licit opium is used to manufacture those medicinal needs that directly or indirectly are produced from morphine. About 90 percent of this opium goes for morphine production (4). Poppy straw processing has been the only alternative to raw opium as a source of morphine. Poppy straw has become an increasingly important source of morphine over the past decade. However, about 65 percent of total licit morphine production still comes from raw opium (4). Morphine is an addictive drug and very rarely is used directly for medical purposes. Ninety-five percent of morphine is now converted into other substances, mainly codeine (19). Opium contains 10 to 12 percent morphine (17).

2. Codeine

Codeine is the most important opium derivative for medical needs. This alkaloid has been recognized for many years as a safe and effective pain reliever and cough suppressant (19). Codeine is the most widely used anti-tussive and it is also extensively used as a mild analgesic (17, 18, 19, 22).

All the codeine (methylated morphine) used in health care in the United States is obtained from imported opium or concentrated from opium poppy straw (19, 22). About 90 to 95 percent of the legally produced morphine is converted into codeine (18, 19). In 1979, more than half of the opium held for emergency use in the United Nations' strategic materials stockpile was released to meet the opium demand for codeine production (19). So far, no satisfactory synthetic substitute has been found for codeine which is totally accepted in medicine (19).

3. Heroin, the Opium Disaster

Although opium is the source for many important and beneficial drugs, it is also the base for heroin, one of the most dangerous addicting drug of abuse. Opium smoking and eating is also common among the people of many countries and opium addiction has been a very serious problem in these countries. Opium is one of the most important groups, if not the most important one, from the standpoint of drug abuse (17).

"Opium and its alkaloids are no ordinary medicine; the addicting and narcotic effects of morphine, heroin, etc., give rise to a considerable international social problem" (9). Morphine, extracted from illicit opium, is converted to heroin illegally, using a relatively easy process (19). One hundred percent of illicit production of morphine is converted to heroin (32). For this reason, opium "is now the only source of certain drugs needed to protect the public welfare -- but its misuse harms society" (19). Heroin now is the most abused illicit drug in the United States (32).

D. Opium Poppy Seed Oil

Poppy seed and poppy seed oil production in Russia and some European countries is as important as the production of opium. Among the oilseed crops, the poppy deserves more attention as it contains good quality cooking and industrial oil (31). Poppy seed oil is second in quality only to olive oil (16). It is superior to sunflower oil in taste and keeping quality (31). Poppy seed oil has good drying properties and is not strongly colored; thus, it is suitable for making the better quality oil colors used in painting.

Opium poppy seed contains 48 to 52 percent oil on a dry weight basis (31). Oil content in this poppy is an independent character and there is no negative correlation between opium production and oil content. Thus, the present classification of poppy into "oil" and "opium" varieties is not correct. There are no varieties exclusively for oil or for opium. Opium poppy seed oil is rich in unsaturated fatty acids, especially oleic acid (31).

Some experiments have shown that although oil content of this poppy is slightly different for different places of cultivation, it is a fairly constant character in different varieties of this poppy and is independent of any agronomic practices. However, the seed yield varies significantly, depending on the environmental conditions (31).

Whole poppy seed are used widely in the confectionary and baking industries. Also, the oilcake, left after extracting the oil from the seed, contains about 32.5 percent protein and 10 percent oil and is used as a concentrate in feeding pigs and other animals produced for meat (31). An average for poppy seed yield seems to be 675 kilograms per hectare. Eleven hundred kg of opium poppy seed per hectare was reported for the poppy grown in Arizona in 1950 (17). In 1975, the United States paid $2,500,000 for imported opium poppy seeds used for culinary purposes (17).

II. Papaver bracteatum

The ultimate in narcotic control would be the worldwide prohibition of opium production. However, as long as opium is the only source of some important medical needs, it will need to be produced. Opium production could be entirely banned when there is an adequate substitute, other than opium, for codeine production. Regarding this problem, scientists of different nations have been working cooperatively to find a substitute for opium and opium poppy production in order to not only solve the world opium shortage problem but also to eliminate the worldwide opium abuse in illicit drug production. *Papaver bracteatum*, so far, has shown very good potential to meet these goals.

A. Botanical and Agricultural Classifications

Papaver bracteatum was first recognized as a species by Lindley in 1821 (6). This plant is a perennial species of the family Papaveraceae. *P. bracteatum* is closely related to *P. orientale* L. and *P. pseudo-orientale* L. (21). Peter Goldblatt (11) did a biosystematic study on these species and he confirmed that these three species belong to the Section "Oxytona" of the Papaveraceae family, versus *P. somniferum* and some other poppies which are in the Section "Papaver." Although some authors claim that *P. bracteatum* has some distinct characteristics which clearly distinguish it from the other species of its Section (8), it was reported by some workers (21) that it is not possible in all cases to distinguish between these species in the wild state. *P. bracteatum* is important for its alkaloid thebaine. The other two species of the same Section yield practically no thebaine; therefore, it is very important to know the factors by which *P. bracteatum* can be distinguished from the other species of this Section and from any other species of the family Papaveraceae.

In the second meeting of the United Nations working group on P. bracteatum (22), it was reported that P. bracteatum can be distinguished from other species of the family by having all of the following characteristics: (a) three to several bracts immediately under the calyx; (b) deep red flower with dark markings; (c) short peduncle with cauline leaves extending three-quarters of the length of the stem; (d) heavily serrated leaves; (e) chromosome number 2n = 14; (f) predominant alkaloid thebaine.

B. Origin and Natural Habitat

P. bracteatum grows wild in two separate areas in Iran; the Alborz Mountains north and northwest of Tehran, and in Kurdistan in western Iran. A third group of plants occurs on the north slope of the Cacasus Mountains in Russia, widely separated from both Iranian groups (21). The largest group is the Alborz Mountain group where P. bracteatum grows in vast areas -- on the slopes facing the Caspian Sea, in rocky mountains at altitudes ranging from 2,000 to 3,000 meters above sea level. The other Iranian group is located in lower altitudes in western Iran. This species is well adapted to a comparatively dry environment. It often grows on stoney slopes from 1,500 to 2,500 meters above sea level. This plant has grown well in Europe, North American, Israel, Australia, and India (8).

C. Plant Origin and Its Alkaloids

It has been reported that P. bracteatum produces small amounts of isothebaine, protopine, salutaridine, and other minor alkaloids along with the thebaine (8). However, it seems that the occurrence of these alkaloids in the plant depends on the germplasm source and also on the stage of plant development. Bohm (2) reported that a thebaine-strain of this plant species (all collections from Iran) contained essentially only the thebaine alkaloid in full-grown plants while E-strain plants (collections from Russia) contained thebaine and alkaloid E in mature plants. He later mentioned that (3) alkaloid E (alpinigenine) occurred in the aerial parts of young plants but disappeared at maturity in thebaine-strain plants while it remains in the E-strain group. Cheng and Doorenbos (5) reported that the total number of detectable alkaloids for all different germplasm decreased with plant age. The quantity of all alkaloids except thebaine also decreased with the age of plants. They could not find any detectable amount of morphine or codeine in the varieties that they studied.

1. Thebaine and its importance

Thebaine has been known since 1835 when it was isolated from capsules of *P. somniferum* by Pelletier (5, 18). Many other species of the Papaveraceae family, as well as some species of other plant families, are known to contain thebaine (5). Crude thebaine is a toxic material but it can be converted to codeine (the most important alkaloid for pharmaceutical manufacturing) easily and in good yield (18). In fact, the principle for this conversion is being used in licit drug manufacturing to convert thebaine from opium to codeine (21). For many years thebaine was extracted from opium in small amounts as a by-product and was usually discarded as a useless material. However, during the past half century it has been used to produce some important drugs for medical purposes. None of them have been reported to be of any significance in drug abuse (19).

Thebaine is not subject to abuse. Morphine, the base for heroin, cannot be obtained from thebaine except through a series of complicated and inefficient chemical processes (12). Since codeine derived from opium has never been used as a source of heroin, codeine derived from thebaine seems to be safe from abuse by drug traffickers (12, 19). Other useful substances (such as naloxone, hydrocodone, and oxycodone) may be also derived from thebaine (13).

2. Thebaine content in *P. bracteatum*, its distribution in the plant and its economic yield

Great variation in thebaine content has been found in wild strains of *P. bracteatum* L. (5, 21, 22, 29, 32). Thebaine content variation within plants of the same collection and even for different capsules of the same plant, have been reported (33). It was reported early that the latex of some wild growing Iranian *P. bracteatum* contained 26 percent of thebaine on a dry weight basis. Ninety-eight percent of the alkaloid content of *P. bracteatum* was found to be thebaine (20). Some years later, a new population of this species was found in Western Iran which was claimed to contain 3.5 percent thebaine in dried capsules (14, 30). No other alkaloid was found in this population, so almost pure thebaine was obtained after one crystallization of the extract (14). This thebaine content is more than three times higher than the best previously reported thebaine producing plant (30). This new collection was called "Arya II" versus the previous collection from the Alborz Mountains of Iran which had been called "Arya I." Later, in a large scale experiment with "Arya II" materials, the thebaine content of the plants was reported at 2.3 percent (15). However, it was found later (32) that although the capsule thebaine content was higher in "Arya II" plants than in "Arya I" plants, the total thebaine yield of the latter population was found to be more than that of the former one. The magnitude of the difference by which "Arya I" exceeded "Arya II" in total thebaine yield per plant was attributed to differences in vigor of plants. Plants of another accession (PI 381607) that were also collected in western Iran have characteristics similar to those of Arya II plants. It has been reported (32) that the total capsule thebaine yield of accession PI 381607 is lower than that for accession PI 383309 (Arya I). Similar to Arya II it was attributed to the smaller capsules of accession PI 381607 compared to accession PI 383309 (Arya I). Thus, it was suggested that the total yield potential of thebaine should be considered for commercial growth of this plant rather than just considering the thebaine concentration (32).

Thebaine distribution in plant parts strongly depends on the germplasm source and stages of plant development. In "Arya I" plants, thebaine distribution in plant parts was reported (32) as follows: root, 60 percent; leaf, 13 percent; stem, 12 percent; and capsule, fifteen percent. The distribution for aerial parts of "Arya II" plants was: petals, 12.60 percent; stigmas. 7.78 percent; bracts, 22.3 percent; young leaves, 0.25 percent; stems, 12.73 percent; and capsules, 44.25 percent. Considerable variation has been found in the analytical results for various methods of thebaine determination (22). Variation among reports about thebaine content and distribution in this species could be attributed to this problem.

The significant variation in thebaine concentration of this plant species suggests genetic differences among the germplasm sources (6).

Thus, to develop plants of the greatest economic potential, selection of germplasm from within and between collections would be required (6). Experiments so far have indicated that the genetic characteristics of P. bracteatum are more important than ecological conditions for the production of plants with a high yield of thebaine (21, 29). There are adequate morphological, cytological, and chemical methods available to identify the thebaine rich strains (21). Plants rich in thebaine usually have the following characteristics: (a) bud shape; oval to oblong; (b) bracts; flower buds closely surrounded by 5 to 8 imbricated bracts; (c) calyx; covered with coarse hairs; (d) petals; 5 to 6 deep red petals present (21).

3. Plant age, its stage of development and thebaine yield

Thebaine can be found in P. bracteatum plants from the seedling stage (22). The wide range of thebaine content reported for some plant organs could be attributed mostly to differences in the age of the plants at the time of analysis. It is generally believed that thebaine content increases with plant age (22). It has also been reported that the absolute amount of thebaine in the plant increases during the first three weeks of growth and then remains fairly constant (16).

Shoot thebaine concentration of this plant has been found to vary significantly within populations of 18- and 31-week-old plants. The overall mean thebaine concentration on a percent of air-dry basis for shoots of older plants was found to be almost twice that of younger plants (6). A significant difference was observed between thebaine concentration of the roots for 18-week-old plants, but not for 37-week-old plants (6). Cheng and Doorenbos (5) studied the alkaloid content of several varieties of P. bracteatum throughout the growth period and they concluded that thebaine content of this plant peaks when plants are seven months old. This was confirmed by Vincent et al. (32) when they observed that the thebaine content of 14 accessions declined about 20% between 7 and 11 months of plant age.

The highest total amount of thebaine seems to occur in the thick storage roots. Thirty kg per hectare yields of thebaine have been reported by harvesting the roots of two-year-old plants (20). Fairbairn and Hakim (8), however, only got yields of 8 kg thebaine per hectare from root material. That was probably because they studied plants of a low yielding strain.

To obtain an economic thebaine yield, however, from the agronomic point of view, the use of the above-ground plant parts is preferred to roots. The plant is a perennial and in the first year does not produce much root or aerial parts; often there are only a few flowers. From the second year of age, however, aerial parts can be collected annually and almost certainly by mechanical means (8). The United States Department of Agriculture tested 300 accessions growing together in Washington state and it was found that most of them flower at about the same time (22).

In determining the thebaine content of capsules, it has been suggested to record the developmental stage (days from flower opening) of the capsules analyzed (28). Lalezari (22) claimed that thebaine content in the upper 30 cm portion of the P. bracteatum stem is still high enough for worthwhile recovery.

It is generally believed that the maximum amount of thebaine occurs in the capsules three to four weeks after petal opening

(8, 9, 10, 22, 29, 33). The yellow-green capsules collected just prior to maturity and open-air dried in the shade were found, however, to have the maximum percent of thebaine (24, 29). It has also been reported that the peak thebaine concentration occurs during the day at about 1500 hr. (10). This may be due to the low water content of capsules at this time of the day (29).

Harvesting at the time of maximum thebaine content of the capsules may not necessarily be the most economical (28). Although some results showed that the thebaine content peak for "Arya I" plants occurred during the first 3 to 4 weeks after flower opening, a second peak was observed 5 to 6 weeks after petal opening (10). At this fully ripe stage, a theoretical thebaine yield of 50 kg per hectare has been reported (10). Mechanized capsule harvesting may be best at about 5 to 7 weeks after petal opening. Avoiding drying costs and obtaining seed of higher quality are other advantages of capsule harvesting at this time (10, 28).

Some evidence indicates that as this perennial plant increases in age, the capacity for thebaine production increases. The highest yield has been reported to be obtained in Iran from plants several years old (21). Old wild roots contained 1.7 to 2.1 percent thebaine, whereas those from 10-month-old plants contained 0.7 percent. The thebaine content of capsules and stems was more constant and ranged from 0.85 to 1.1 percent and 0.2 to 0.3 percent, respectively. Thebaine yields of 7 kg per hectare (dried capsules plus peduncle) have been reported for the strains with just 0.4 percent thebaine in capsules (8). Cultivation of P. bracteatum would yield, after the second or third year, 4000 to 7000 kg of dried aerial parts and about

3500 kg of dry weight of root material per hectare (22). With the average of one percent thebaine content, this would yield 40 to 70 kg of thebaine per hectare.

D. Plant Material Preconditioning and Thebaine Yield

Some evidence suggests that the difficulties of analysis of P. bracteatum for thebaine may be further compounded by the deterioration of alkaloid during storage (32). Kuppers, et al (25) studied the effects of some environmental factors on thebaine decomposition. They reported that although light and oxygen do not significantly affect thebaine, the temperature to which thebaine is exposed is of great importance. Cheng and Doorenbos (23) conducted a series of drying experiments with P. bracteatum plant material. They could not find any differences in analysis of 15^{o}C dried samples and those of 40^{o}C dried samples. They suggested that plant material should be dried at 40^{o}C temperature prior to analysis. They added that all dried plant parts pick up moisture if exposed to the air.

In the second meeting of the United Nations working group on P. bracteatum (22), it was decided that all plant samples be air-dried at 60^{o}C prior to thebaine analysis in order to facilitate comparison of different methods of thebaine analysis. It has been generally accepted that freeze-drying is the most suitable method for pre-conditioning of plant parts for quantitative thebaine analysis (26, 27, 32). Thirteen to seventeen percent less thebaine was extracted from 15^{o}C oven-dried tissues than from freeze-dried tissues, in all tissues examined (32). Storage of raw harvested plant material, even under ideal conditions, led to a loss of thebaine of 12 to 20 percent in one year (10).

E. Seed Oil, Its Quality and Yield

There is very little information on P. bracteatum seed oil. However, it is known that the oil is qualitatively similar to that obtained from P. somniferum seed (22, 28). It seems that, apart from the oil, only proteins and carbohydrates are present in the seeds of this plant species. For the "Arya I" seeds, 27 percent fat, 27.3 percent protein, and 40.4 percent carbohydrates have been reported. For the first generation of the same seed grown in Norway, just 18 percent fat was reported along with 25 percent protein and 40 percent carbohydrates (22). No information was found in the literature on the seeds' oil content or yield on a unit area basis.

F. Seed Germination, Environmental Effects

There is no information available about the effects of capsule harvest time or seed pre-conditioning on the percent of seed germination. It is known, however, that the seeds germinate well in the temperature range of 10 to 25^{o}C (22, 28, 34). Temperatures over 25^{o}C are detrimental to seed germination (33). Ripe, freshly harvested seeds were found to be dormant but maximum germination was achieved after storage for several months in dry conditions (33).

III. Comparison of Papaver bracteatum and opium poppy; their economic potential and their social problems

P. bracteatum has been considered as a potential commercial source of thebaine that can be converted to codeine. It can fill the gap between supply of opium and demand for codeine, thus eliminating opium production and its connection with drug addiction.

A. Economic Potential

Papaver bracteatum is a perennial plant and, therefore, significantly different from opium poppy which is an annual (18, 19, 22, 23). It matures over three years and although some plants are known to be 15 to 20 years old, the plant seems to be economically productive for 8 to 10 years. The equivalent codeine yield of this plant per unit area is 5 to 10 times higher than that for the opium poppy (19).

Considering an average yield of 12 kg of opium per hectare, from capsules, (8, 9, 17, 20) and an average 12 percent of morphine for opium (17), opium poppy yields about 1.5 kg of morphine per hectare. Using the opium poppy straw as a source gives the same per hectare yield of morphine (9). This totals to 3 kg of morphine per hectare. Even if there were a 100 percent conversion rate of morphine to codeine the 3 kg/ha yield does not compare favorably with the 15 kg/ha yield of codeine from thebaine produced by P. bracteatum (8, 22). The cost of cultivating P. bracteatum, processing the straw, and converting its thebaine content to codeine has been known to compare favorably with the cost of utilizing opiums, and seems to be less than the cost of using opium poppy straw for codeine production (19).

B. Social Problems

Papaver bracteatum can solve the codeine supply problem without creating new abuse problems or aggravating present abuse problems (19). P. bracteatum, unlike the opium poppy, does not produce either opium or morphine. Rather, it produces only the alkaloid thebaine and in a high yield. It could be the world's first source of codeine that has no accompanying drug addiction problems (19). Since the plant requires three years to mature, illegal production of _P. bracteatum_ would be very difficult (19). Introducing the use of thebaine as a source for codeine instead of morphine, that has been the primary source for codeine production so far, can bring a drastic reduction of the use of opium poppy, and as a result, decrease all drug addiction problems related to opium.

Mallinckrodt, Inc. (19) has prepared a chart comparing the abuse potential of _P. bracteatum_ and opium poppy. This chart is given on the following page.

Abuse Considerations of *Papaver bracteatum* vs. *Papaver somniferum* (Opium Poppy)*

Papaver bracteatum	Opium Poppy
Perennial -- 3 years to mature, more time to locate illicit fields and destroy	Annual -- 6 months to produce opium
Contains thebaine only -- no morphine	Contains morphine, thebaine, codeine, etc.
Thebaine is destroyed by acids and isolation is tricky	Morphine is relatively stable and isolation from opium is easy
Thebaine is poisonous and cannot be used as such by addicts	Opium and morphine are used directly by addicts
Thebaine is very difficult to convert to morphine and heroin; complicated chemical steps with flammable reagents -- not suitable for clandestine laboratories	Morphine is easy and safe to convert to heroin; single chemical step with common reagents -- easy clandestine operation
Thebaine derivatives -- hydrocodone and oxycodone can be made -- both have been known for 50 years. No significant record of abuse	Thebaine derivatives -- hydrocodone and oxycodone can be made -- both have been known for 50 years. No significant record of abuse
Bentley compounds require for production great technical skill and sophisticated equipment. The process is dangerous because of risk of fire and poisoning of operator	Bentley compounds require for production great technical skill and sophisticated equipment. The process is dangerous because of risk of fire and poisoning of operator
Bentley compounds have no record of abuse	Bentley compounds have no record of abuse

*Prepared by Mallinckrodt, Inc. (1974), Mallinckrodt and Second Streets, St. Louis, Missouri 63147

MATERIALS AND METHODS

I. Location, climate, and soil of the experimental site

The experiment was conducted at the Hyslop Crop Science Field Laboratory at Oregon State University. The field laboratory is located in the heart of the Willamette Valley, about 10 kilometers northeast of Corvallis. The site is at a latitude of 49^{0} and 38' north and the elevation at this location is about 75 meters above sea level (1).

The climate of the area is described as a modified marine type. The winters are usually wet and mild and the summers are dry and warm. The average length of time between killing frost during the growing season is 215 days. The normal annual precipitation is about 1000 mm with 70 percent of this occurring during the five months of November through March, while less than 5 percent of the total occurs during the three summer months (1). Air temperature and precipitation means for the two crop years of experiment duration and their deviation from the normals are given in Appendix 1, Table 1.

The soil of this field laboratory is classified as a Woodburn silt loam (fine, silty, mixed Mesic aqualtic Argixeroll). This is a well-drained soil with a pH of 5.5 to 5.8. It is well supplied with most nutrients but crops respond to nitrogen, phosphorus and sulfur fertilizers.

II. Materials and field procedures

Seeds of two *Papaver bracteatum* accessions, PI 383309 (Arya I)* and PI 381607, were obtained from the plant introduction station in Pullman, Washington. Both accessions are from collections of Northern Iran and had shown good potential for thebaine production (32).

*Plant Introduction (U.S. Department of Agriculture)

Plants were direct-seeded in a split-plot design with four replications in April 1976. Each plot was one meter wide and seven meters long and consisted of one row. Plots served as borders to each other throughout the conduct of the experiment. The extremities of the plot area contained extra border rows. Five tons of lime per hectare had been applied on the field in September, 1975. About 330 kg/ha of 16-20-0 fertilizer was incorporated in the soil prior to planting. The soil surface was kept wet with sprinkler irrigation for several weeks. The plots were hand-weeded several times during establishment. In the spring of 1977, the plots were thinned to 25 plants per row. Fifty kg of nitrogen per hectare (as 21-0-0) was applied on the plots in March, 1977. The same amount of this fertilizer was again applied in March, 1978. Two and one-half kg/ha of boron was applied in October, 1977. An application of 330 kg/ha of 16-20-0 fertilizer was made in October 1978 after the first harvest season. Two and one-half kg/ha of diuron was applied in November of this year to control the annual weeds. Plants were not irrigated after the first year of establishment.

III. Data collection and analytical methods

The poppy plants did not flower in the first year after seeding and, therefore, they did not produce any capsules in 1976. In the spring of 1977, when the plants were one year old, there were a few capsules, but not enough to be harvested for data collection. In the spring of 1978, when the plants were two years old, there were many capsules in the plots and, thus, this year was chosen as the first year to harvest the capsules.

In 1978, different rows of each accession in every replication were randomly selected to be harvested on different dates. Seven harvest dates, with one week intervals, were chosen. Each single row for a different harvest date was considered as a subplot, while the accessions in each replication were the main plots. Thus, the data were collected and analyzed as a split-plot design in this year.

The first capsule harvest was on June 21, 1978. That was four weeks after the poppies were in full bloom. The last harvest was seven weeks later on August 2. In each harvest, the capsules (along with the peduncle) were clipped by hand. These capsules were hung outside in cloth sacks to get dry enough for further measurements. In September, the capsules were cleaned, the bracts were removed and the seeds were shaken out of the capsules by hand. Peduncles were clipped to leave 15 cm attached to the capsules. It was previously reported (22) that the thebaine content of this part of the peduncle (stems) is high enough to be extracted economically. Clean capsules, along with 15 cm of the peduncle, were weighed for each sample. These data are given in Appendix 1, Table 4. These capsules were also counted. The number of capsules for each plot is given in Appendix 1, Table 4. Seeds of each plot were cleaned* and weighed separately. These data are present in Appendix 1, Table 7.

Significant differences were not obtained for the concentration of thebaine in the capsules or seed oil content for samples harvested on different dates. It was previously reported that pre-storage conditioning of harvested material might change the thebaine concentration in those materials. Thebaine is not very stable under some stor-

*Seeds were cleaned with an Oregon Vibratory Purity Separator.

age conditions. Thus, it was thought that some physical, chemical, or biochemical reactions taking place in harvested plant materials during storage may significantly affect the capsule thebaine content, seed oil concentration, or seed germination for samples harvested on different dates. Therefore, in 1979, it was decided to study the effects of pre-storage drying of harvested plant material on the above factors. To do so, the capsules of each plot were divided into two parts. The capsules of the first part were treated exactly like those for the year 1978. The capsules of the other part were dried in a fan-forced air dryer at $40^{0}C$ ($105^{0}F$) temperature for 48 hours, immediately after harvesting. The other procedures and methods were the same as described for the year of 1978. Capsule number, capsule weight and seed weight of each plot for both methods of pre-storage drying are presented in Appendix 1, Tables 5, 6, 8 and 9. In order to study the interactions, the data for 1979 were analyzed as a split-split plot design. The methods of plant material drying were considered as the sub-sub-plots in this year.

In both years of the study. the numbers obtained for different measurements were rounded off to the closest numbers wherever needed.

A. Thebaine Yield

Two components were measured in order to calculate the thebaine yield as affected by the harvest date; the weight per capsule (capsule yield) and the capsule thebaine concentration.

1. Weight per capsule (capsule yield)

The weight per capsule was calculated by dividing the total capsule weight of each plot by the capsule number of the same plot.

These data are presented in Appendix 1, Tables 4, 5, and 6.

2. Thebaine concentration

Twenty-five capsules (along with 15 cm of the peduncle) were randomly selected for each sample. These capsules were shipped to Philadelphia* for thebaine analysis. In 1979, thebaine concentration was measured for the samples of just accession 383309 that were dried in the dryer. That was because of governmental restrictions on the capacity to analyze samples for thebaine concentration. Consequently, there was insufficient time to wait for more data to include in this report. Available data are given in Appendix 1, Tables 2 and 3.

B. Oil Yield

Two components were measured in order to study the effect(s) of harvest time on oil yield; seed weight per capsule and oil content of the seed.

1. Seed weight per capsule

Seed weight per capsule was calculated by dividing the total seed weight of each plot by the capsule number of the same plot. These data are given in Appendix 1, Tables 7, 8, and 9.

2. Seed oil content

In order to measure oil content in the seeds of this plant species, the method suggested by Comstock and Culbertson (7) was used. The steps applied in this method are summarized as follows:

Step 1. Oven dry seed and envelopes for 16-18 hr. at 105^{o}C.

Step 2. Weigh 5 grams of seed and press at approximately 2000 kg/cm^2

Step 3. Soak in hexane 72 hr. in envelope.

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*USDA Science and Education Administration. Agricultural Research, Northeastern Region, Eastern Regional Research Center, 600 East Mermaid Lane, Philadelphia, Pennsylvania 19118.

Step 4. Oven dry - 16-18 hr. at 105°C.

Step 5. Weigh and calculate oil content.

The oil content was measured for each plot separately. These data are presented in Appendix 1, Table 10.

C. Seed Germination

One hundred seeds of each plot were counted and placed in petri dishes on wet filter papers. The dishes were placed in growth chambers with constant light and temperature. The light intensity was 50 foot candle and the temperature was 25°C. Seeds were watered twice a week. The germinated seeds were counted and removed from the dishes three times, at weekly intervals. The first counting was done one week after seeding. The total number of germinated seeds after four weeks of seeding are presented in Appendix 1, Table 11.

RESULTS AND DISCUSSION

I. Thebaine Yield

The effects of harvest date on two thebaine yield components were studied separately; capsule thebaine concentration and capsule yield.

A. Capsule thebaine concentration

1978

Thebaine concentration of capsules of both accessions was very inconsistent for different harvest dates in 1978 (Appendix 1, Table 2). Although the variability of thebaine concentration in the capsules of this plant species, as affected by internal or external factors, is well documented, this much variation in thebaine concentration for different harvest dates is quite unusual. The variation within replications is also very large. The exceptionally high thebaine concentration of the capsules of both accessions for just two replications on the sixth harvest date is unexplainable unless it is due to errors in thebaine analysis. However, because of limitations on the analytical laboratory capacity, and time shortage involved in this study, the data were statistically analyzed as received.

Thebaine concentration in the capsules of both accessions was significantly (.05 level) different for harvest date treatment in 1978 (Appendix 2, Table 1). Thebaine concentration of the capsules of accession PI 381607 increased very rapidly on the second harvest date and then decreased (Figure 1). The second and higher peak was obtained on the sixth harvest date. Thebaine concentration then decreased after this date to the level lower

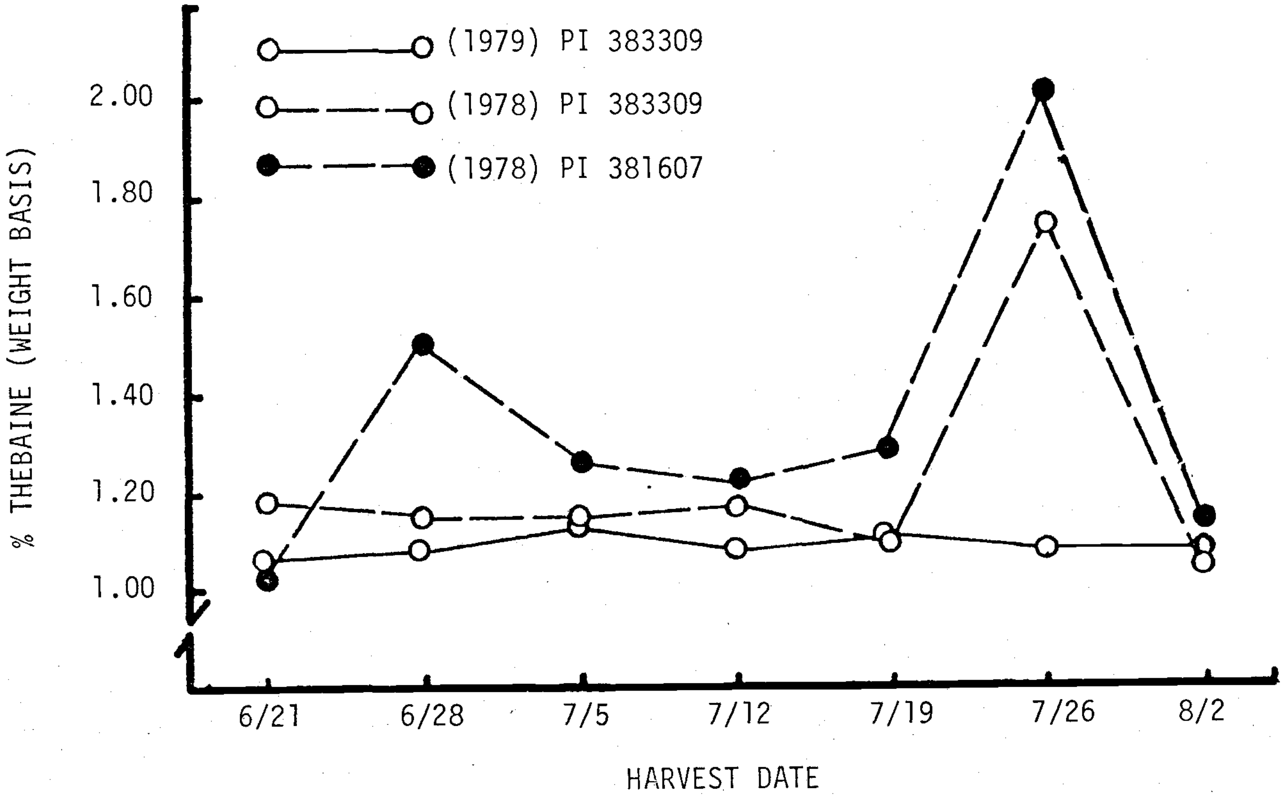

Figure 1. Percent thebaine concentration of the open-air-dried capsules (along with 15 cm of peduncle) of two Papaver bracteatum accessions for seven harvest dates in 1978 and for dryer-dried capsules of accession PI 383309 in 1979.

than that for any other date except the first one. The first peak was not observed for accession PI 383309. However, after a slight decrease in thebaine concentration of this accession on date five, the peak occurred on the sixth harvest date as it also did for accession PI 381607 (Figure 1). Capsule thebaine concentrations of accession PI 381607 on dates two and six were significantly (.05 level) higher than any other dates. Capsule thebaine concentration was only significantly (.05 level) higher on the sixth harvest date for accession PI 383309 (Table 1).

Thebaine concentration of capsules of accession PI 381607 was significantly (.05 level) higher than that for accession PI 383309 (Appendix 2, Table 1). The average percent thebaine in the capsules (along with 15 cm of the peduncle) of accession PI 381607 for seven harvest dates was 1.34, while it was 1.22 for accession PI 383309 (Table 1). Percent thebaine (air-dried basis) of accession 381607 capsules was higher than that for accession PI 383309 on all harvest dates except for the first one (Table 1 and Figure 1). However, the variation of thebaine concentration in the capsules of accession PI 381607 for different harvest dates was also higher than that for accession PI 383309. Replications were significantly different at the 0.01 level in 1978 (Appendix 2, Table 1). This is merely because of very large differences between the thebaine concentration of both accessions on the sixth harvest date for replications 1 and 2, compared to those for replications 3 and 4, which is believed to be due to some errors in thebaine analysis. Harvest date x accession interactions were not significant.

Table 1. Average percent thebaine of capsules (along with 15 cm of attached peduncle) on a dry weight basis, of Papaver bracteatum accessions PI 383309 and PI 381607 in 1978 and accession PI 383309 in 1979, harvested on seven dates, and their means.

Year	Accession	Harvest Dates 6/21	6/28	7/5	7/12	7/19	7/26	8/2	$\bar{x}$[2]
1978 open-air dried samples	PI 381607	1.02 a[1]	1.50 b	1.25 a	1.22 a	1.28 a	2.01 b	1.13 a	1.34
	PI 383309	1.18 a[1]	1.13 a	1.12 a	1.18 a	1.08 a	1.75 b	1.05 a	1.22
	$\bar{x}$	1.10 a[1]	1.31 a	1.18 a	1.20 a	1.18 a	1.88 b	1.09 a	
1979 dryer-dried samples	PI 383309	1.06 NS[3]	1.07 NS	1.11 NS	1.08 NS	1.10 NS	1.08 NS	1.08 NS	1.08

[1]Numbers followed by the same letter are not significantly different at the 0.05 level. Read horizontally.

[2]Numbers beside a continuous single line are not significantly different at the 0.05 level.

[3]Not significantly different.

1979

Since the thebaine analyses were obtained just for accession PI 383309 and for dryer-dried samples in 1979, these data (Appendix 1, Table 3) were analyzed as a completely randomized block design. The capsules were harvested on the same dates as those in 1978 and were dried in the dryer at 37°C (100°F) for 48 hr. Percent thebaine in the capsules of accession PI 383309 harvested on seven different dates was not significantly different (Appendix 2, Table 2). Thebaine concentration in the capsules of this accession was much more consistent for different harvest dates in 1979 (Table 1 and Figure 1) than in 1978.

Year Interactions

Thebaine concentration of the capsules of accession PI 383309 was significantly (.05 level) higher in 1978 than in 1979 (Appendix 2, Table 5). The average percent thebaine of the capsules (along with 15 cm of the peduncle) of this accession for seven harvest dates was 1.08 in 1979 while it was 1.22 in 1978 (Table 1). The capsules were open-air-dried in 1978; whereas, they were dryer dried in 1979. Thus, the actual differences for thebaine concentration in the two years might be even greater than measured in this study. However, it is obvious that thebaine concentration of the capsules did not fluctuate on different harvest dates in 1979 as widely as that in 1978 (Table 1, Figure 1). Year x harvest date interactions were not significant (Appendix 2, Table 5).

B. Capsule Yield

Since the number of capsules was different in different plots, the weight per capsule was measured as a yield component that can be affected by harvest date.

1978

The weight per capsule did not significantly change on different harvest dates for either accession in 1978 (Appendix 2, Table 3). However, it increased slightly for the first three harvest dates for both accessions (Figure 2). The weight per capsule for both accessions peaked on the fifth harvest date and decreased slightly on the sixth and seventh harvest dates (Table 2, Figure 2). It seems that the capsules continue development until the fifth harvest date. Accession PI 383309 produced heavier capsules on all harvest dates than accession PI 381607 (Figure 2). Average weight per capsule of accession PI 383309 for seven harvest dates was 2.55 grams compared to 2.43 grams for accession PI 381607 (Table 2). However, this difference between the capsule weight of the two accessions was not significant (Appendix 2, Table 3).

1979

The weight per capsule (capsule yield) of neither accession was affected significantly by the date of harvest. This was true for both methods of pre-storage capsule drying (Appendix 2, Table 4). However, the effects of drying methods on the capsule weight of both accessions was significant at the 0.01 level. This is simply due to differences in the water content of capsules after drying. Obviously, open-air-dried capsules held more water

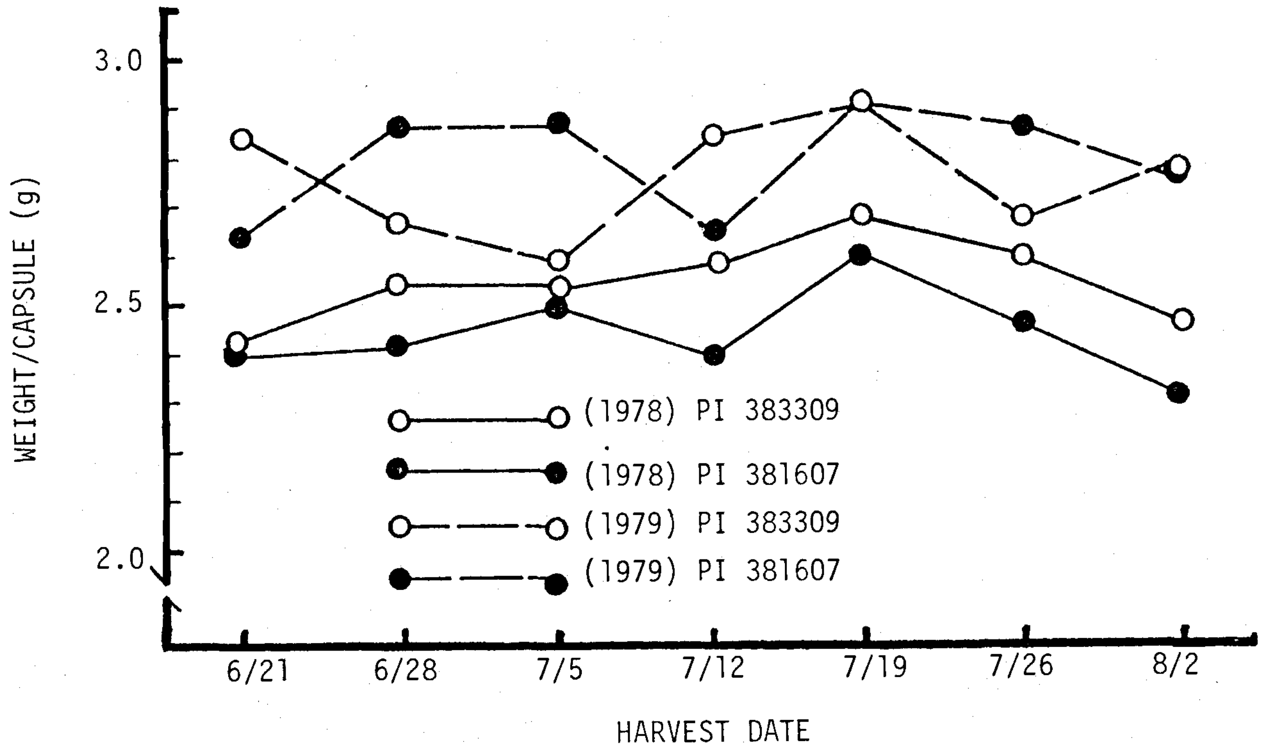

Figure 2. Weight per capsule of two Papaver bracteatum accessions for seven harvest dates of open-air-dried samples in 1978 and 1979.

Table 2. Average weight per capsule in grams (along with 15 cm of attached peduncle) of *Papaver bracteatum* accessions PI 383309 and PI 381607 for dryer-dried samples and seven harvest dates in 1978 and 1979, and their means.

		Harvest Dates[1]								
Year	Accession	6/21	6/28	7/5	7/12	7/19	7/26	8/2	$\bar{x}$[2]	$\bar{\bar{x}}$[2]
1978 open-air dried	PI 383309	2.43	2.54	2.54	2.59	2.70	2.60	2.48	2.55	
	PI 381607	2.39	2.42	2.49	2.39	2.60	2.45	2.29	2.43	
	$\bar{x}$	2.41	2.48	2.51	2.49	2.65	2.52	2.38		2.49
1979 open-air	PI 383309	2.82	2.68	2.58	2.82	2.91	2.70	2.78	2.77	
	PI 381607	2.67	2.85	2.85	2.67	2.91	2.85	2.74	2.79	
	$\bar{x}$	2.74	2.76	2.71	2.74	2.91	2.77	2.76		2.78

[1]None of the horizontal numbers are significantly different.

[2]Numbers beside a continuous single line are not significantly different at the 0.05 level.

than dryer-dried capsules, and thus, they weighed more (Appendix 1, Tables 5 and 6). For open-air-dried samples, weight per capsule of both accessions fluctuated slightly for different harvest dates (Figure 2). In contrast to the year of 1978, the difference in 1979 between the average capsule weight of the two accessions was very small for the open-air-dried samples (Table 2). However, this difference was bigger for dry-dried samples (Appendix 1, Table 6, and Figure 3). It seems that capsules of accession PI 381607 hold more water than accession PI 383309 at the harvest time. This can be attributed to the fact that capsules of accession PI 381607 mature a few days later than accession PI 383309. The harvest date x accession interactions were not significant (Appendix 2, Table 4). The drying methods x harvest dates x accessions interactions were significant at the 0.05 level. This can be also attributed to the different moisture levels that the capsules of each accessions hold on different harvest dates.

Year Interactions

The average weight per capsule of the two accessions for open-air-dried samples and for seven harvest dates in 1978 and 1979 were compared in order to study the year interactions. The capsule yield of both accessions was significantly (0.01 level) higher in 1979 than in 1978 (Appendix 2, Table 6; Figure 3). The average weight per capsule for the two accessions and seven harvest dates was 2.49 grams in 1978 and 2.78 grams in 1979 (Table 2). The year x harvest date interactions were not significant (Appendix 2, Table 6).

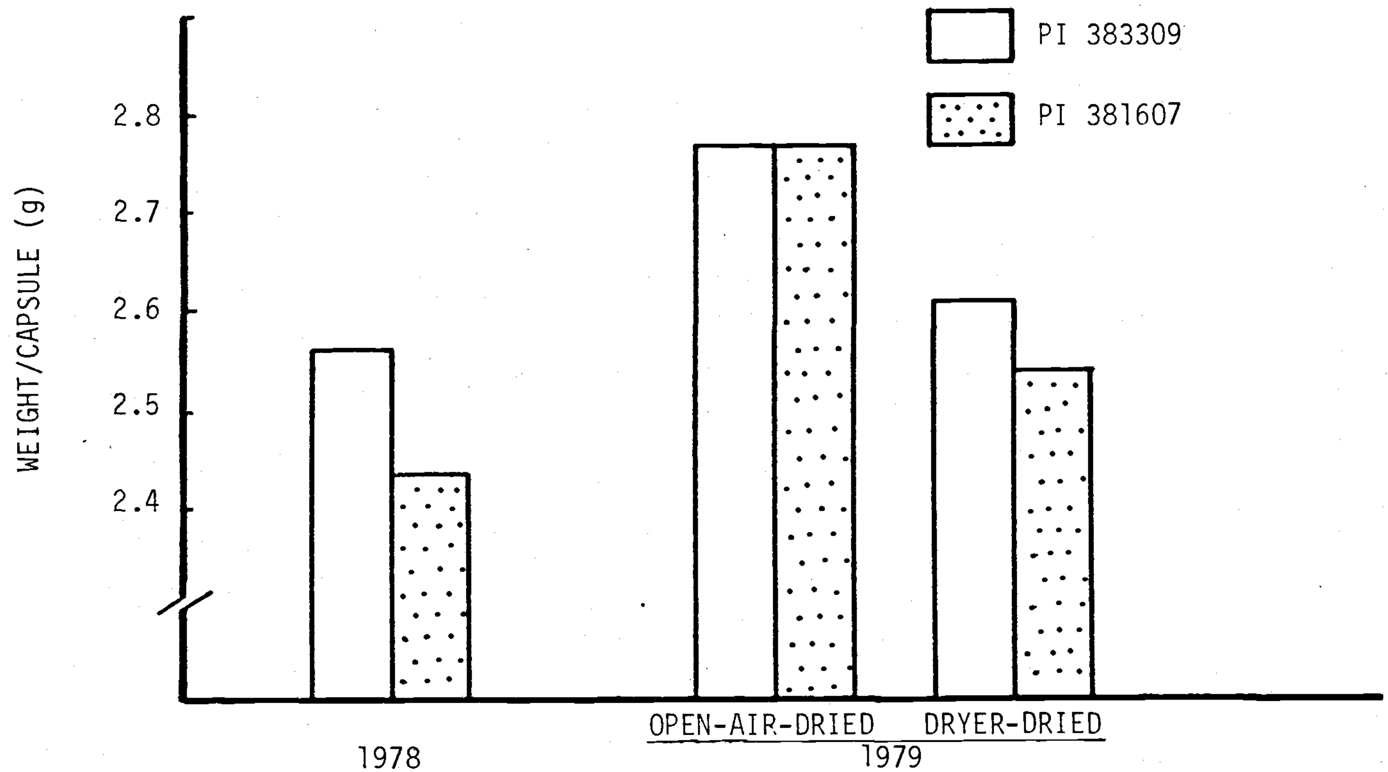

Figure 3. Weight per capsule (along with 15 cm of peduncle) of two *Papaver bracteatum* accessions averaged over seven harvest dates for open-air-dried samples in 1978 and two drying methods in 1979.

C. Thebaine Yield

Thebaine yield was measured by multiplying the weight per capsule of each plot by the capsule thebaine concentration of the same plot.

1978

Harvest date significantly (0.05 level) affected the total thebaine yield of both accessions in 1978 (Appendix 2, Table 7). Since the weight per capsule was not significantly affected by the harvest date, thebaine concentration of capsules for different harvest dates was the only factor affecting the thebaine yield on different harvest treatments. Both accessions yielded higher on the sixth harvest date than any other harvest date (Figure 4). However, thebaine yield on the sixth harvest date is not significantly higher than for harvest dates one, three, four, and five for accession PI 383309 and harvest date two for accession PI 381607 (Table 3). The notable result obtained in this analysis was that the total thebaine yield of the two accessions were not significantly different from each other (Appendix 2, Table 7). Although the thebaine concentration of the accession PI 381607 capsules was higher than that for accession PI 383309 (Figure 1), the weight per capsule of the latter accession was higher than that for the former one (Figure 3). However, the average total thebaine yield for seven harvest dates of accession PI 381607 was higher than for accession PI 383309. Thebaine yield was 3.30 grams for 100 capsules (along with 15 cm of peduncle) of accession PI 381607, while it was 3.10 grams for accession PI 383309 in 1978 (Table 3). Harvest date x accession interactions were not significant.

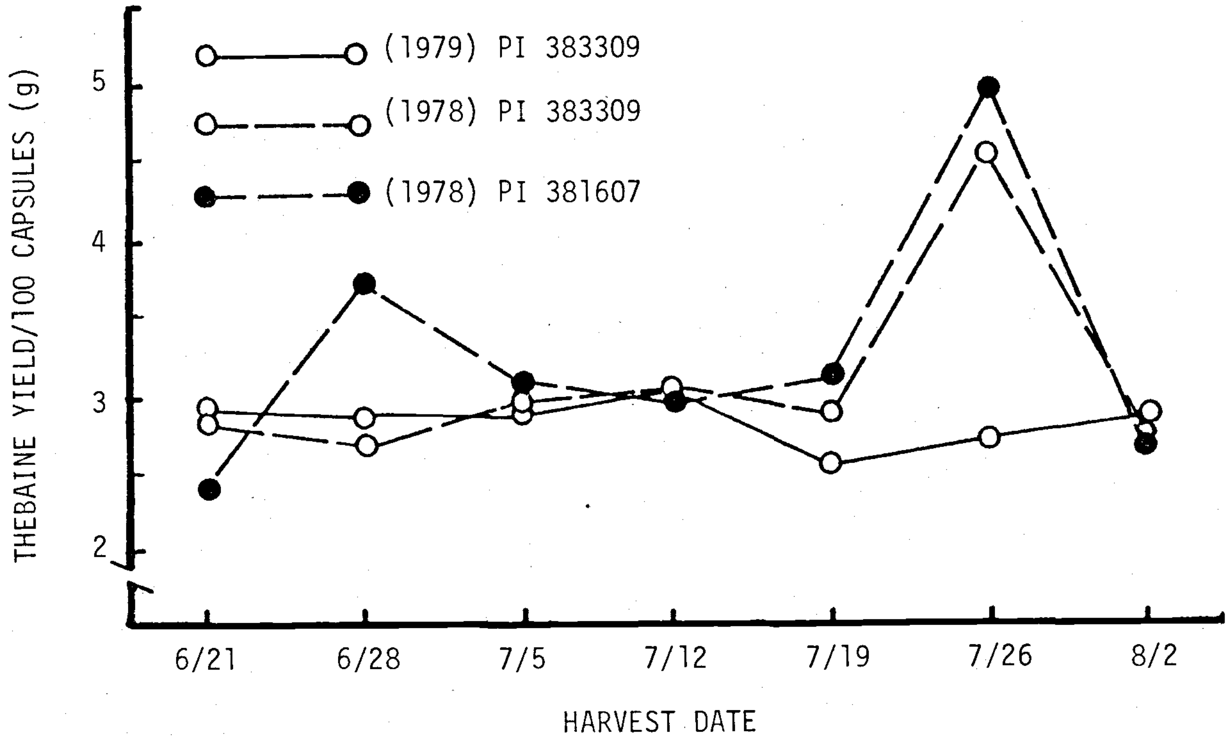

Figure 4. Thebaine yield of capsules (along with 15 cm of peduncle) of two Papaver bracteatum accessions for seven harvest dates and open-air-dried samples in 1978 and dryer-dried samples of accession PI 383309 in 1979.

Table 3. Average total thebaine yield (g/100 capsules plus 15 cm of peduncle) of <u>Papaver bracteatum</u> accessions PI 383309 and PI 381607 for seven harvest dates and open-air-dried samples in 1978, and for accession PI 383309 and for seven harvest dates and dryer-dried samples in 1979, and their means.

Year	Accession	Harvest Dates 6/21	6/28	7/5	7/12	7/19	7/26	8/2	$\bar{x}$[3]
1978 open-air-dried samples	PI 381607	2.43 a[1]	3.72 ab	3.11 a	2.89 a	3.11 a	5.00 b	2.63 a	3.30
	PI 383309	2.87 ab[1]	2.74 a	3.05 ab	3.02 ab	2.93 ab	4.48 b	2.65 a	3.10
1979 dryer-dried sampes	PI 383309	2.92 NS[2]	2.94 NS	2.98 NS	2.97 NS	2.58 NS	2.65 NS	2.79 NS	2.83 NS

[1]Numbers that are followed by the same letter are not significantly different at the 0.05 level. Read horizontally.

[2]Not significantly different.

[3]Numbers beside a continuous single line are not significantly different at the 0.05 level.

1979

Since the results of thebaine analysis was available for only dryer-dried samples of accession PI 383309 in 1979, total thebaine yield was calculated only for these samples. The data were analyzed as a completely randomized block design. According to this analysis (Appendix 2, Table 8), the total thebaine yield of accession PI 383309 did not differ significantly on different harvest dates in 1979. The maximum thebaine yield occurred on the third harvest date and declined very slightly thereafter until the fifth harvest date, after which the yield increased slightly again (Table 3, Figure 4). The small fluctuation in thebaine yield for different harvest dates in 1979 was due to slight changes in capsule yield. Thebaine concentration of capsules were very consistent in 1979. Also, the total thebaine yield of accession PI 383309 was much more consistent for different harvest dates in 1979 than in 1978 (Figure 4).

Year Interactions

Although thebaine yield of the capsules of accession PI 383309 was higher in 1978 than in 1979, the analysis of variance did not show any significant differences between the thebaine yield of this accession in the two years (Appendix 2, Table 9). Thebaine concentration in the capsules of this accession was higher in 1978. However, bigger capsules in 1979, which elevated the capsule yield, compensated for lower thebaine concentration in the capsules. Average total thebaine yield in 100 capsules (along with 15 cm of peduncle) of accession PI 383309 for seven harvest dates was 3.10

grams in 1978, while it was 2.83 grams in 1979 (Table 3). Year x harvest date interactions were not significant for total thebaine yield (Appendix 2, Table 9).

II. Oil Yield

The effects of harvest dates and pre-storage drying methods on two oil yield components were studied; seed yield and seed oil content.

A. Seed Yield

Since the number of capsules was not the same for all the plots, seed weight per capsule was measured for each plot as an oil yield component that can be affected by harvest date.

1978

Highly significant differences (0.01 level) were detected for seed weight per capsule of accession PI 383309 harvested on seven dates (Appendix 2, Table 10). Differences in the seed weight per capsule of accession PI 381607 harvested on different dates were significant at the 0.05 level (Table 4). The seed weight per capsule of both accessions reached the maximum on the third harvest date (Table 4, Figure 5). The slight increase in seed weight during the first three harvest dates is believed to be due to the seed filling in the capsules, even though the seeds were found to be viable since the first harvest date. The seed yield of both accessions declined after the third harvest date. This decrease was due to both seed drying and seed shattering. However, since all the seeds were weighed several weeks after harvest, it was assumed that the moisture content of all samples had equilibrated. Thus, the effects of moisture content on the seed weight harvested

Table 4. Seed weight (g) per capsule (air dry basis) of *Papaver bracteatum* accessions PI 383309 and PI 381607, harvested on seven dates and open-air-dried in 1978 and 1979, and their means.

Year	Accessions	Harvest Dates 6/21	6/28	7/5	7/12	7/19	7/26	8/2	$\bar{x}$[3]	$\bar{\bar{x}}$[4]
		grams/capsule								
1978 open-air-dried	PI 383309	.354 AB[1] ab[2]	.378 AB a	.417 A a	.382 AB a	.355 AB ab	.268 B b	.265 B b	.345	
	PI 381607	.315 A[1] ab[2]	.313 A ab	.347 A a	.259 A ab	.278 A ab	.242 A b	.223 A b	.282	.313
1979 open-air-dried samples	PI 383309	.794 A[1] a[2]	.704 A a	.673 A a	.682 A a	.402 B b	.329 B b	.356 B b	.568	
	PI 381607	.687 AB[1] a[2]	.760 A a	.621 ABC a	.459 BCD b	.433 CDE b	.289 DE c	.242 E c	.492	.530

[1]Numbers that are followed by the same capital letter are not significantly different at the 0.01 level. Read horizontally.

[2]Numbers that are followed by the same small letter are not significantly different at the 0.05 level. Read horizontally.

[3]Numbers beside a continuous single line are not significantly different at the 0.05 level.

[4]Numbers beside a continuous double line are not significantly different at the 0.01 level.

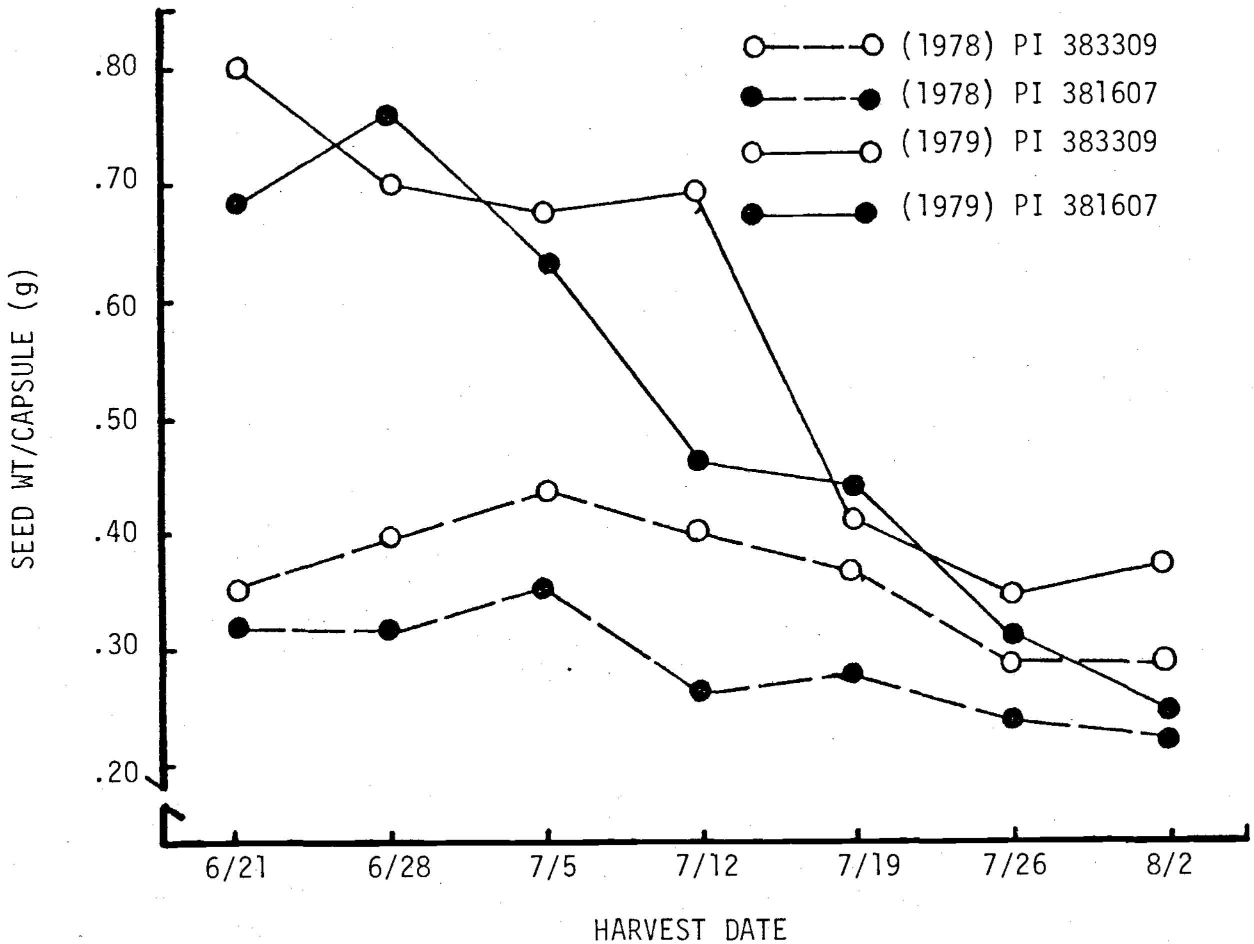

Figure 5. Seed weight per capsule of two Papaver bracteatum accessions for seven harvest dates of open-air-dried samples in 1978 and 1979.

on different dates should be negligible. Seed shattering after the third harvest was found to be very severe for both accessions. The highest seed yields for both accessions were obtained on the third harvest date when seeds reached their maximum development and the capsules' holes still were not open enough to allow seed shattering. Seed yield of accession PI 383309 did not change significantly until the sixth harvest date (Table 4). The seed yields for the last two harvest dates were significantly (0.01 level) lower than for the third harvest date. The seed yield of accession PI 381607 on the third harvest date was significantly (0.05 level) higher than those for the last two harvest dates (Table 4). For all harvest dates, accession PI 383309 produced more seed than accession PI 381607 (Figure 5). The average seed weight per capsule of accession PI 383309 for seven harvest dates was .345 grams, while it was only .282 grams for accession PI 381607 (Table 4). Nevertheless, the analysis of variance failed to show significant differences between the seed yield of the two accessions. Harvest date x accession interactions were not significant (Appendix 2, Table 10).

1979

Analysis of variance exhibited a highly significant effect (0.01 level) of harvest date on the seed yield of both accessions (Appendix 2, Table 11). The effects of drying method on the seed weight per capsule of both accessions were also highly significant (0.01 level). However, as was true for capsule weight, this effect was merely due to the differences between moisture levels held by the seed dried with two different methods. Drying methods are not expected to affect the seed weight per capsule on an oven-dry basis.

Seed weight per capsule of accession PI 383309 was highest on the first harvest date and decreased for all subsequent harvest dates. However, this decrease was very slight until the fourth harvest date, after which the seed yield dropped very sharply (Figure 5). Seed yield of accession PI 381607 increased slightly after the first harvest date. It was maximum on the second harvest date and then decreased very sharply until the last harvest date. These data indicate that the seeds of accession PI 383309 were physiologically mature on or before the first harvest date in 1979. Seed shattering for this accession was not severe until after the fourth harvest date. This is because the capsules' holes were not wide enough to allow seed shattering until the fifth harvest date. Seed of accession PI 381607 were still developing after the first harvest date but soon after that, on the second harvest date, they reached their maximum weight. Seed shattering occurred immediately after the second harvest date, indicating that the capsules' openings were wide enough at that time to permit seed shattering (Figure 5).

The seed yield of accession PI 383309 (for the open-air-dried samples) was not significantly different for the first four harvest dates in 1979 (Table 4). However, it was significantly (0.01 level) lower for the last three harvest dates. For accession PI 381607, seed yield was not significantly different for the first three harvest dates. Seed yield of this accession on the fourth and fifth harvest date are significantly (0.05 level) lower than that for earlier harvest dates, while they are significantly (0.05 level) higher than for later two harvest dates.

As was true in 1978, seed weight per capsule was generally higher for accession PI 383309 than for accession PI 381607. Average seed weight for seven harvest dates of open-air-dried samples of accession PI 383309 was 0.568 grams in 1979, while it was 0.492 grams for the other accession (Table 4). However, the analysis of variance did not detect any significant differences between the seed yields of the two accessions. Harvest date x accession interactions were not significant. All other interactions like drying method x harvest date x accession, were found not to be significant in 1979.

Year Interactions

The average seed weight per capsule of the two accessions for open-air-dried samples and for seven harvest dates in 1978 and 1979, were evaluated for year interactions. Seed weight per capsule of both accessions was significantly (0.01 level) higher in 1979 than in 1978 (Appendix 2, Table 14; Figure 6). The average seed weight of the two accessions for seven harvest dates was 0.313 grams per capsule in 1978, while it was 0.530 grams in 1979 (Table 4).

The year x harvest date interactions were significant at the 0.01 level of probability. This is because the date of seed development and ripening in 1979 was a few days earlier than in 1978. Maximum seed development in 1978 was on the third harvest date while the seeds of accession PI 383309 were already ripe on the first harvest date in 1979 (Figure 5). The seed weight per cap-

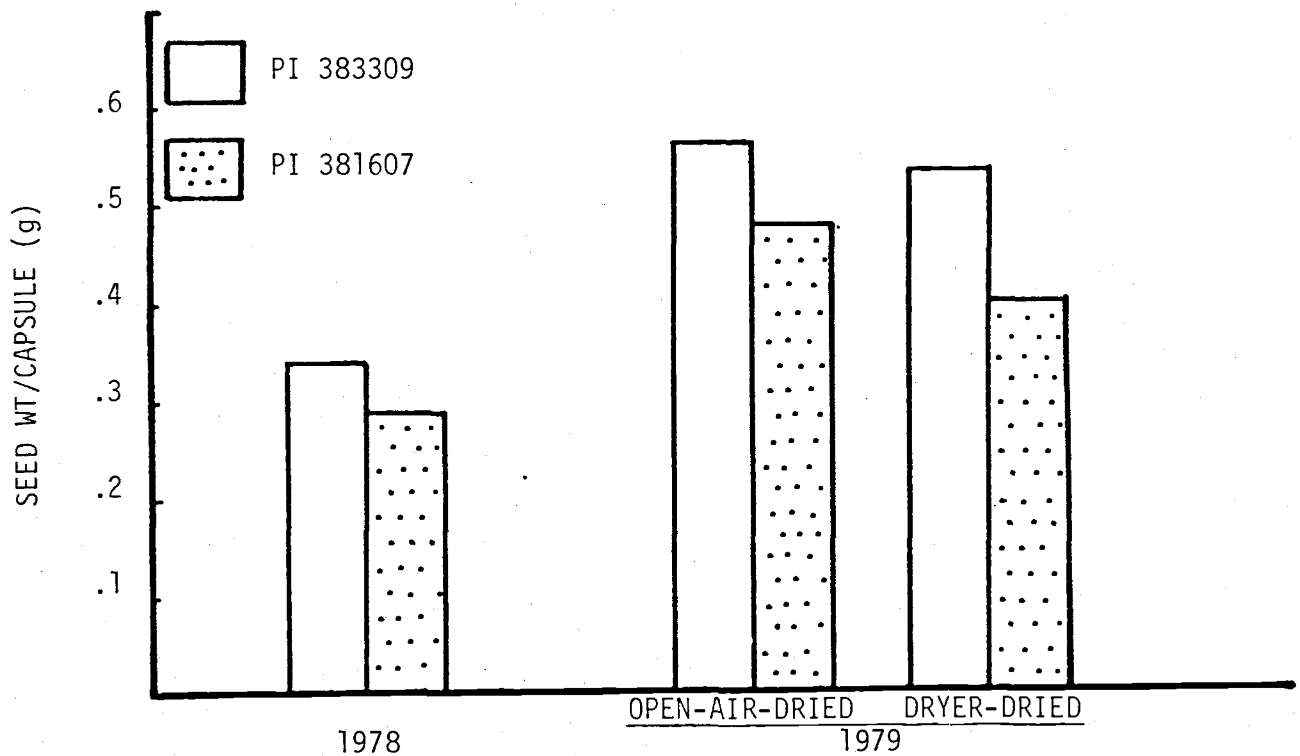

Figure 6. Seed weight per capsule of two Papaver bracteatum accessions averaged over seven harvest dates for open-air-dried samples in 1978 and two drying methods in 1979.

sule of accession PI 381607 reached a maximum on the second harvest date in 1979.

B. Seed Oil Content

1978

Analysis of variance showed no significant differences among the oil content of the seeds of the two accessions harvested on seven harvest dates in 1978 (Appendix 2, Table 12). Oil content of bcth accessions (percent, oven-dry basis) fluctuated slightly for different harvest dates (Figure 7). The oil content for the seeds of accession PI 383309 was higher than that for accession PI 381607 in all cases except the first harvest date. The average seed oil content of accession PI 383309 for seven harvest dates was 46.38 percent, while it was 45.75 percent for accession PI 381607 (Appendix 1, Table 10). This difference between the seed oil content of the two accessions, although very small, was found to be highly significant at the 0.01 level of probability (Appendix 2, Table 12). The seed oil content of accession PI 383309 was maximum on the fourth harvest date while it was minimum for the seeds of the other accesssion on that date. Nevertheless, harvest date x accession interactions were not significant.

1979

As was true in 1978, the seed oil content of the two accessions did not significantly change on different harvest dates (Appendix 2, Table 13). Also, the pre-storage drying method did not significantly affect the seed oil content of the two accessions harvested on seven different dates. For both drying methods,

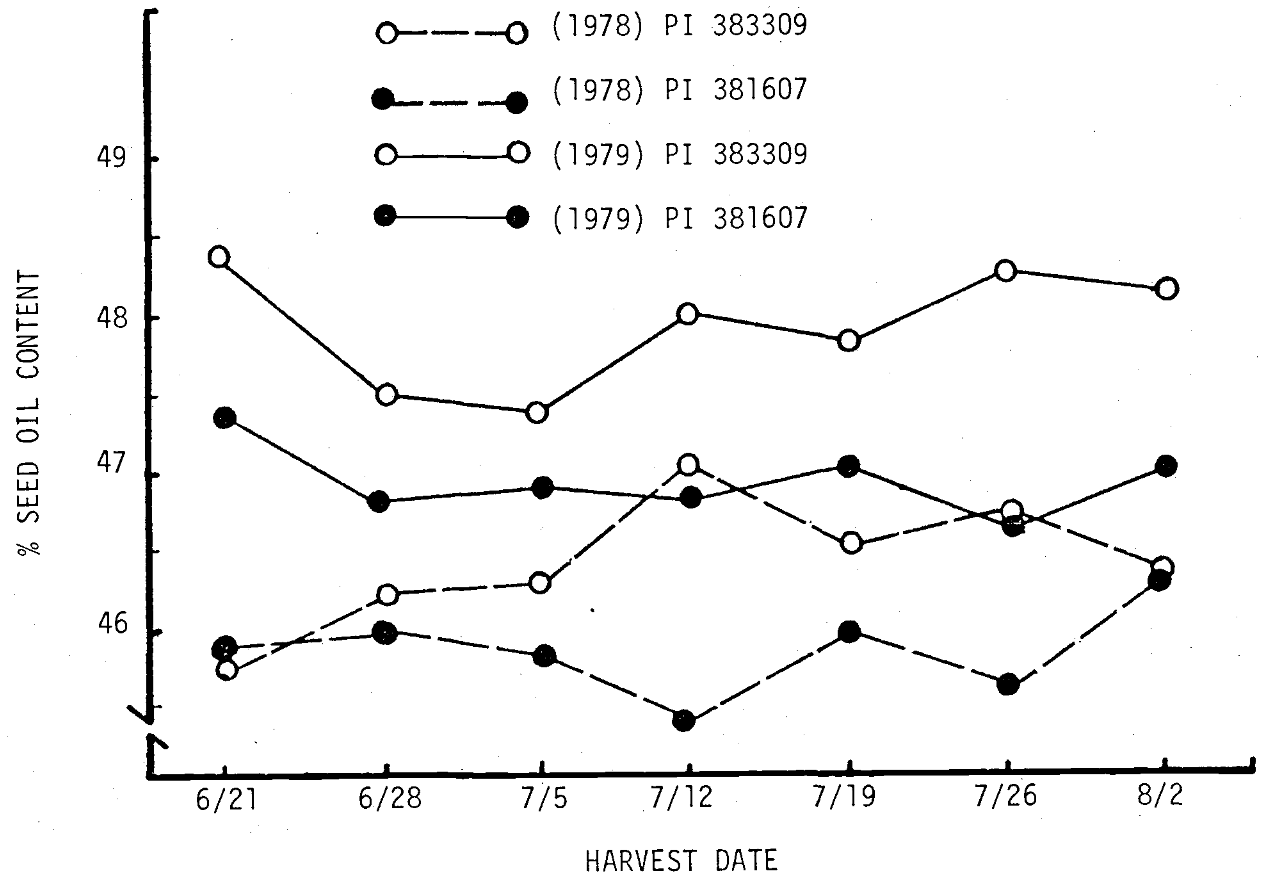

Figure 7. Percent seed oil content of two *Papaver bracteatum* accessions for seven harvest dates and for open-air-dried samples in 1978 and average of two drying methods in 1979.

the seed oil content of accession PI 383309 was higher than that for accession PI 381607 (Appendix 1, Table 10), but the differences were not statistically significant (Appendix 2, Table 13). Percent seed oil of accession PI 383309 was higher than that of accession PI 381607 on all harvest dates (Figure 7). All other interactions like drying method x accession, drying method x harvest date, and drying method x harvest date x accession, were found not to be significant.

Year Interactions

The seed oil content of both accessions were higher in 1979 than in 1978 (Figure 8). The average seed oil content of accession PI 383309 for seven harvest dates was 46.33 percent in 1978 while it was 47.88 percent for the average of two drying methods in 1979 (Appendix 1, Table 10). These figures for accession PI 381607 were 45.75 percent and 46.95 percent in 1978 and 1979, respectively. The differences of the seed oil content of the two accessions between 1978 and 1979 were found to be significant at the 0.05 level of probability (Appendix 1, Table 10; Appendix 2, Table 15). The year x accession interactions were not significant.

C. Total Seed Oil Yield

In order to calculate the total seed oil yield of the two accessions harvested on seven different dates, seed weight per capsule of each plot was multiplied by the oil content of the seeds of the same plot.

1978

Seed oil yield (grams of oil in seeds from 100 capsules) of

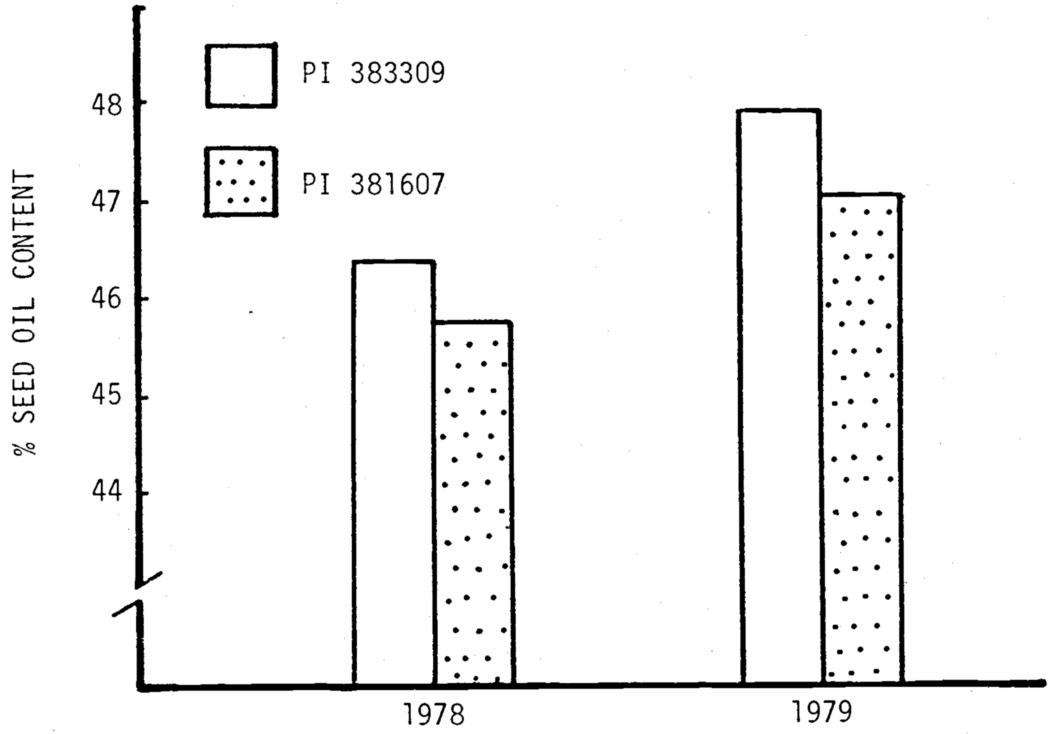

Figure 8. Percent seed oil content of two <u>Papaver bracteatum</u> accessions, averaged over seven harvest dates, for open-air-dried samples in 1978 and the average of two drying methods in 1979.

the two accessions were not significantly different for different harvest dates in 1978 (Appendix 2, Table 16). Since the oil content of the seed was very stable for both accessions on different harvest dates, seed yield is the only oil yield component which affected the total seed oil yield on different harvest dates. Fluctuation of seed oil yield for harvest dates (Figure 9) is almost exactly the same as that for the seed yield in 1978 (Figure 5). Seed oil yields of both accessions were maximum on the third harvest date. The yield for both accessions decreased after this harvest date. However, the analysis of variance did not detect any significant differences for the seed oil yield of the two accessions for different harvest dates.

Seed oil yield of accession PI 383309 was higher than that of accession PI 381607 on all harvest dates (Figure 9). The average oil yield for the seeds of accession PI 383309 for seven harvest dates was 14.82 grams of oil for the seeds of 100 capsules in 1978, while it was 12.04 grams for accession PI 381607 (Table 5). This difference in seed oil yield of the two accessions was found to be significant at the 0.05 level of probability (Appendix 2, Table 16). The harvest date x accession interactions were not significant.

1979

Since the pre-storage drying method did not affect the oil content of the seeds harvested on different dates significantly, and because its effect on the seeds' weight was merely due to the changes in moisture content of the seeds, the total seed oil yield

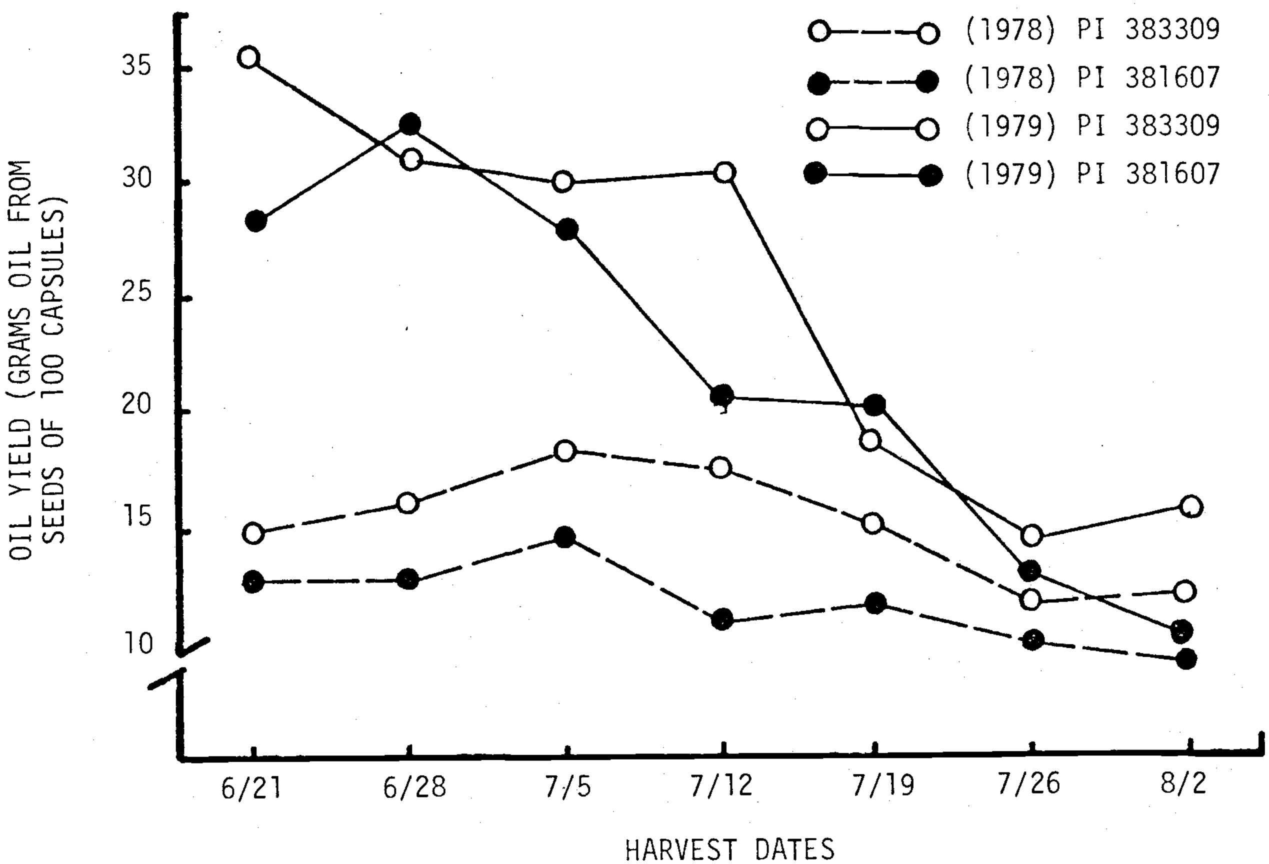

Figure 9. Total seed oil yield of <u>Papaver bracteatum</u> accessions PI 383309 and PI 381607 for seven harvest dates and open-air-dried samples in 1978 and 1979.

Table 5. Average total seed oil yield (grams oil for the seeds of 100 capsules) of *Papaver bracteatum* accessions PI 383309 and PI 381607 for seven harvest dates for open-air-dried samples in 1978 and 1979, and their means.

		Harvest Dates								
Year	Accession	6/21	6/28	7/5	7/12	7/19	7/26	8/2	$\bar{x}$[2]	$\bar{\bar{x}}$[5]
1978 open-air-dried	PI 383309	15.00 NS[1]	16.18 NS	17.49 NS	16.69 NS	15.36 NS	11.65 NS	11.37 NS	14.82	
	PI 381607	13.36 NS[1]	13.37 NS	14.7 NS	11.00 NS	11.92 NS	10.37 NS	9.56 NS	12.04	13.43
1979 open-air-dried samples	PI 383309	35.51 A[3] a[4]	31.19 A a	29.81 A a	30.50 A a	17.82 B b	14.64 B b	15.74 B b	25.03	
	PI 381607	27.71 AB[3] a[4]	33.25 A a	27.30 AB ab	20.32 BC bc	18.89 BCD cd	12.61 CD de	10.56 D c	21.52	23.27

[1]Not significantly different.

[2]Numbers beside a continuous single line are not significantly different at the 0.05 level.

[3]Numbers that are followed by the same capital letter are not significantly different at the 0.01 level. Read horizontally.

[4]Numbers that are followed by the same small letter are not significantly different at the 0.05 level. Read horizontally.

[5]Numbers beside a continuous double line are not significantly different at the 0.01 level.

was calculated for only open-air-dried samples in 1979. The analysis of variance exhibited a highly significant effect of harvest date on the seed oil yield of both accessions (Appendix 2, Table 17). As was true in 1978, this effect was due to the changes of seed yield on different harvest date; the seed oil content of both accessions were very stable on different harvest dates in 1979. The changes in seed oil yield of the two accessions on different harvest dates (Figure 9) follow exactly the fluctuations of seed yields of the two accessions on these dates (Figure 5). The maximum seed oil yield of accession 383309 was obtained on the first harvest date while it was on the second harvest date for accession PI 381607. The seed oil yield of accession PI 381607 dropped very rapidly after the second harvest date, whereas that of accession PI 383309 was fairly constant until the fourth harvest date (Figure 9).

No significant differences were observed in seed oil yield of accession PI 383309 for the first four harvest dates. Neither were there differences among the last three harvest dates (Table 5). However, the seed oil yield of this accession for the first four harvest dates were significantly (0.01 level) higher than those for the last three harvest dates.

For accession PI 381607, the results were quite different. There were no significant differences among the seed oil yield of this accession for the first three harvest dates. The yield on the fourth harvest date was not significantly different from that of the third harvest date. Those of harvest dates four and five were not significantly different (0.05 level). The same was true for harvest dates five and six, and also for harvest dates six and seven (Table 5).

The average seed oil yield of accession PI 383309 for seven harvest dates was higher than that for accession PI 381607. These figures were 25.03 (grams of oil in seeds from 100 capsules) and 21.52, for accessions PI 383309 and PI 381607, respectively (Table 5). However, the analysis of variance did not show any significant difference between the seed oil yield of the two accessions (Appendix 2, Table 17). Harvest date x accession interactions were not significant.

Year Interactions

The average seed oil yield of the two accessions in 1979 was significantly (0.01 level) higher than that in 1978 (Appendix 2, Table 18). The average seed oil yield of the two accessions was 13.43 (grams oil of the seeds of 100 capsules) in 1978 and 23.27 in 1979 (Table 5). The year x harvest date interactions were also significant at the 0.01 level of probability. This is similar to the results found for seed yield. Since the seed oil content of neither accession was significantly affected by the harvest dates, the year interactions for seed oil yield are due to seed yield differences on different harvest dates in the two years. Therefore, the significant year interactions for the average seed oil yield of the two accessions can be explained the same as the year interactions for seed yield.

III. Seed Germination

1978

The date of capsule harvest did not have any significant effect on the percent seed germination of the two accessions (Appendix 2, Table 19). The percent germination of the seeds harvested in 1978 was tested one year later in the summer of 1979. Therefore, the possibility of seed dormancy could not be identified for the seeds harvested in 1978. However, it was noted that in all cases, the seeds of later harvest dates germinated faster and more vigorously than those from earlier harvest dates. Nevertheless, it was found that the seeds of both accessions were viable since the first harvest date, even though they apparently were still developing in the capsules after that date (Figure 10). The percent seed germination of the two accessions for seven harvest dates in 1978 is given in Appendix 1, Table 11.

1979

The effects of harvest date on the percent germination of the seeds of the two accessions were not significant (Appendix 2, Table 20). The pre-storage drying method did not significantly change the percent germination of the seeds harvested on different dates. However, the seed germination percentages for the open-air-dried samples of both accessions were higher than those for dryer-dried samples (Appendix 1, Table 11). It was also noted that the open-air-dried seeds for all the harvest dates germinated much faster and more vigorously than dryer-dried seeds. Also, as was true in 1978, the seeds of earlier harvest dates for both drying methods germinated slower than the seeds that were harvested on later dates. Nevertheless, since no significant differences were detected for the percent of seed germination for the seeds harvested on different dates, it seems that the seeds of both accessions were viable since the first harvest date in 1979 (Figure 10). The percent seed germination of the two accessions for the two pre-storage drying methods and for seven harvest dates is presented in Appendix 1, Table 11.

Year Interactions

Since the pre-storage drying method had no significant effect on the percent germination of the seeds of either accession, the average percent seed germination for both accessions and both drying method in 1979 were compared to those in 1978. There was a significant different (0.01 level) between the percent of seed germination of both accessions in 1978 and 1979 (Appendix 2, Table 21). The average percent seed germination for the two accessions and for seven harvest dates was 82 in 1978, while it was 76 for open-air-dried samples of 1979, and 72 for dryer-dried samples of 1979 (Appendix 1, Table 11, Figure 11). It was mentioned earlier that the germination of all seeds was tested in September of 1979. That was more than one month after the last sample of 1979 was harvested. The data suggest that it is worthwhile to study the existence of possible seed dormancy for this plant species. This dormancy, if it exists, seems to be broken after one year of seed storage. The percent of seed germination for the average of the twoaccessions for seven harvest dates of open-air-dried samples in 1978 and two drying methods in 1979, is shown in Figure 10.

IV. Optimum Capsule Harvest Date for Thebaine Yield, Oil Yield, and Percent Seed Germination.

Percent germination of the seeds of neither accession was significantly affected by the harvest date in the two years of the study. Therefore, seed germination was not considered when determining the optimum capsule harvest date. Total capsule thebaine yield and total seed oil yield are the factors that were used as the basis for determination of the optimum capsule harvest date.

The data for the thebaine concentration of the capsules harvested on different dates in 1978 obtained in this study were of questionable accuracy. Therefore, thebaine yields of only accession PI 383309 in 1979 were the base for determination of the optimum harvest date for total thebaine yield. However, no significant interactions between the capsule thebaine yield of the two accessions harvested on different dates were detected in 1978. The optimum harvest date for the total thebaine yield of accession PI 383309 in 1979 can be considered the optimum harvest date for that of accession PI 381607.

Pre-storage drying method did not significantly affect thebaine concentration or the seed oil content of the capsules harvested on different dates. These yield components were expected to be affected the most. Therefore only the open-air-dried samples in 1979 were considered in the following discussion so that the data obtained in the two years could be compared.

Three different aspects were considered in determining the optimum capsule harvest date: 1) since the thebaine yield is much more important than oil yield from the standpoint of net income to the growers, priority was given to the thebaine yield whenever the two yields did

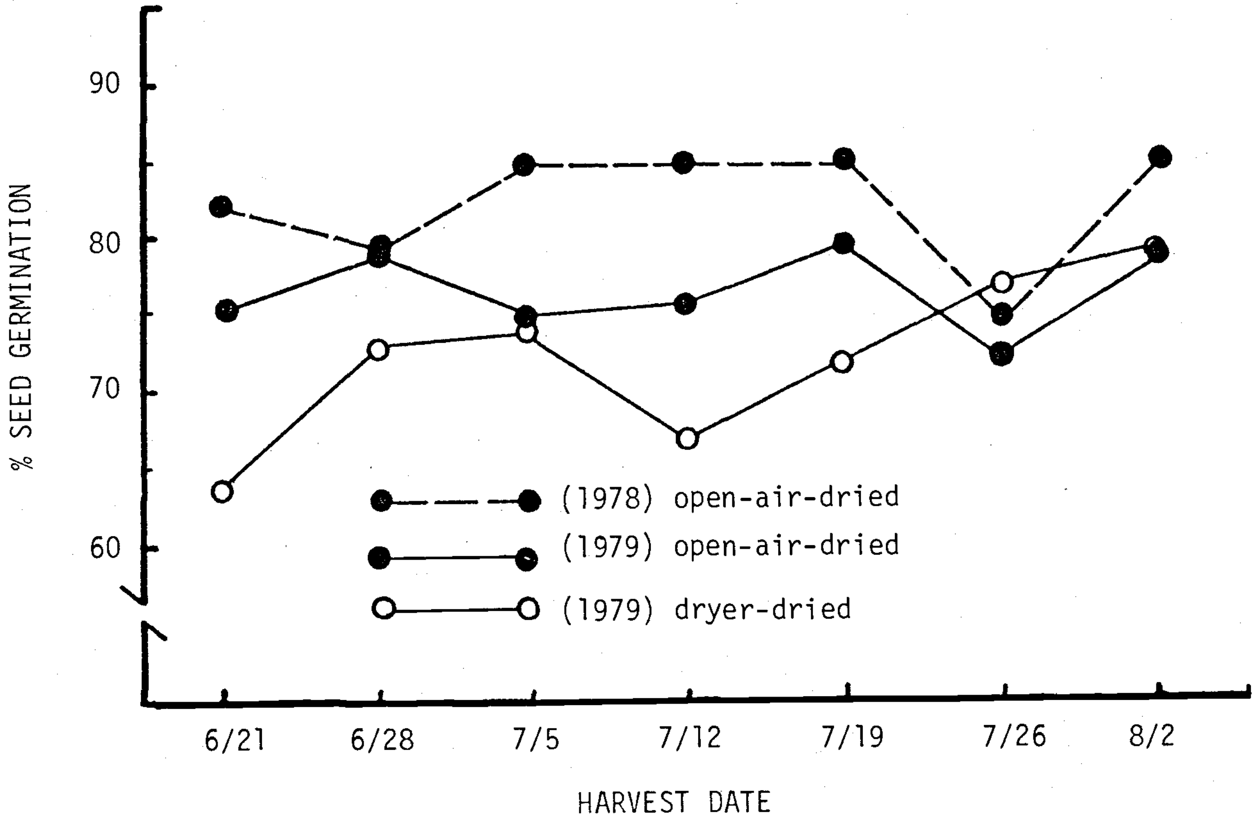

Figure 10. Average percent seed germination of two Papaver bracteatum accessions for seven harvest dates of open-air-dried samples in 1978 and two drying methods in 1979.

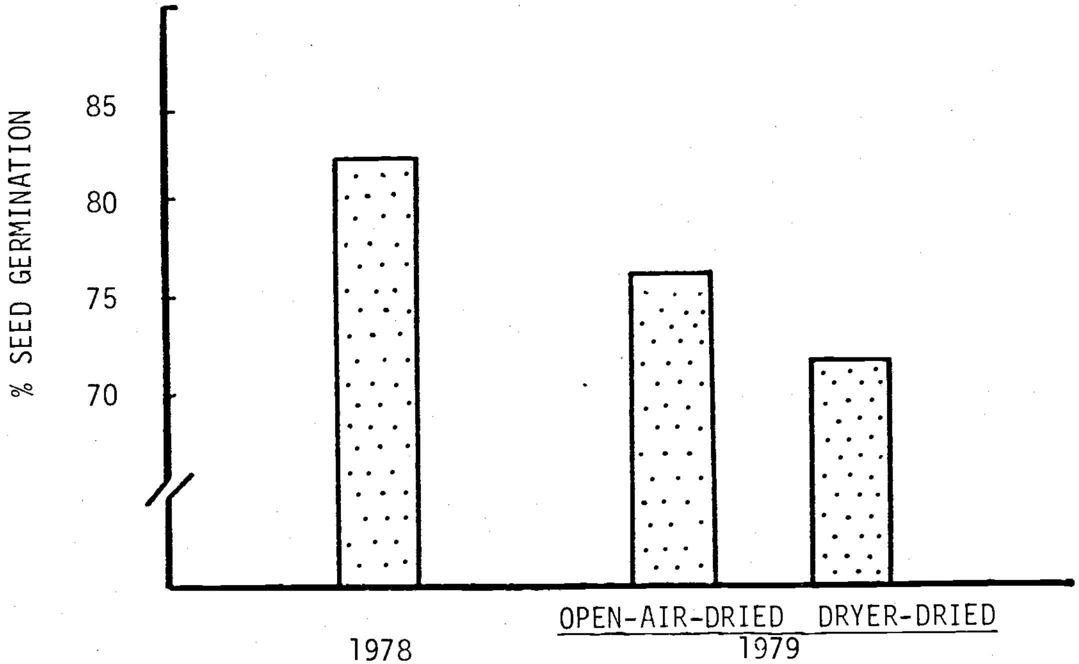

Figure 11. Average percent seed germination of two *Papaver bracteatum* accessions PI 383309 and PI 381607 averaged over seven harvest dates for open-air-dried samples in 1978 and two drying methods in 1979.

not coincide on different harvest dates; 2) year interactions of both yields on different harvest dates were considered and the date on which the yields were more consistent in both years were preferred; 3) the feasibility of mechanized capsule harvesting and the necessity of pre-storage drying for the plant materials harvested on different dates were considered because of their great importance from the economic point of view. In this respect, the date which gives the highest crop yields is not necessarily the optimum harvest date. Considering the above factors and the data obtained in two years, the third harvest date was found to be the best capsule harvest date under the climatic conditions of the experimental site. That date was seven weeks after the crop was in full bloom in both years of the study.

Total thebaine yield of accession PI 383309 was higher on the third harvest date in 1979 (Table 3, Figure 4). Also, the total thebaine yield of both accessions were relatively constant for harvest dates three and four in 1978. Neglecting the data obtained for the second and the sixth harvest dates in 1978, which appeared to have errors in thebaine analysis, total thebaine yield of both accessions are maximum on the third harvest date in 1978 (Table 3, Figure 4).

Although not significantly different, the total seed oil yield of both accessions were maximum on the third harvest date in 1978 (Table 5, Figure 9). There were no significant differences in seed oil yield of the two accessions for the first three harvest dates in 1979 (Table 5). However, this yield was maximum on the first harvest date for accession PI 383309 and on the second harvest date for accession PI 381607 (Table 5, Figure 9). Nevertheless, the seeds of first and second harvest dates were too wet to be separated from the capsules without artificial drying. Also mechanized harvesting of the capsules was found not to be technically feasible before the third harvest date.

Year x harvest date interactions were not significant for total thebaine yield (Appendix 2, Table 9). The interactions were, however, significant for the total seed oil yield (Appendix 2, Table 18). That was because of earlier seed shattering of both accessions in 1979 compared to that in 1978 (Figure 9). But seed loss due to shattering was not significant until the fifth harvest date for accession PI 383309 and until the fourth harvest date for accession PI 381607 in 1979 (Table 5). Therefore, the third harvest date was still considered to be the optimum capsule harvest date in 1979, even though the seed yields were not maximum for either accession on that date.

The capsules of the two accessions were relatively dry on the third harvest date in both years, which allowed storage without further drying. The seeds were also dry enough on that date to be stored without further drying. Seeds were physiologically mature and they were loose in the capsules on the third harvest date in both years. Although the capsules were hand-clipped in this study, it is believed that for commercial production of this crop, mechanized harvesting is quite feasible after the second harvest date. However, more selection and breeding is needed to improve plant uniformity and flower uprightness. It was also found that the capsules harvested on the third date or later can be broken by machines immediately after harvesting and the seeds and capsules can be separated easily by screening. This shows the possibility to operate all harvesting, threshing, and separating in a single process with a combine. This is very important from the economic point of view.

Yield Calculations

Average number of capsules per plot for accession PI 383309 was 185 in 1978 (Appendix 1, Table 4). Since each plot consisted of 7 square meters, the number of capsules in 1978 was 265,000 per hectare. With 3.05 grams of thebaine per 100 capsules on the third harvest date (Table 3), capsules (plus 15 cm of attached peduncle) of accession PI 383309 yielded about 8 kilograms of thebaine per hectare in 1978. With the same procedures of calculation, this accession yielded a little higher than 7 kilograms of thebaine per hectare for open-air-dried samples in 1979. The higher thebaine yield of accession PI 383309 in 1978 was due to higher thebaine concentration in the capsules of this accession in 1978 compared to that in 1979 (Table 1), while the capsule yield was higher in 1979 than 1978 (Table 2).

The capsules of accession PI 381607 (plus 15 cm of attached peduncle) yielded about 8.6 kilograms of thebaine per hectare in 1978. The higher thebaine yield of accession PI 381607 compared to that for accession PI 383309 in 1978, was due to both higher thebaine concentration in the capsules (Table 1) and higher number of capsules per unit area (per plant) for accession PI 381607 (Appendix 1, Table 4). However, accession PI 383309 produced heavier capsules than accession PI 381607 in 1978 (Appendix 1, Table 4).

Capsule thebaine yields obtained in this study were notably lower than the thirty kg per hectare yields of thebaine that have been reported by harvesting the roots of two-year-old plants (20). Fairbairn and Hakim (8) reported yields of only 8 kg thebaine per hectare from root material. In this case, the thebaine yield obtained in this study is comparable since the same amount of thebaine was obtained only by capsule harvesting. The harvest of capsules is much cheaper than the harvest of roots. Also, since the plant is a perennial, capsule harvesting allows for harvesting in the following years without further expenses for crop establishment. However, some years later, Fairbairn (9) calculated yields of 7 kg thebaine per hectare by harvesting the capsules (plus peduncle) of the strains with just 0.4 percent thebaine in the capsules (9). This 7 kg yield is comparable to the findings in this study. However, the average percent thebaine in the capsules (plus 15 cm of peduncle) for the accessions under this study was higher than 1 which is comparatively higher than 0.4 percent reported by Fairbairn (9).

Seed oil yields were calculated using the same procedures as for thebaine yields. In 1978, 17.94 grams of oil was produced from the seeds of 100 capsules of accession PI 383309 harvested on the third date (Table 5). Having 265,000 capsules per hectare, accession PI 383309 would yield 47.5 kg of oil per hectare in 1978. This would be 40.7 kg of oil per hectare for accession PI 381607 harvested on the third date in 1978. Higher oil yield for accession PI 383309 was due to bigger capsules and higher seed weight per capsule than accession PI 381607 in 1978 (Table 4). However, accession PI 381607 produced more capsules per unit area (per plant) than accession PI 383309 in 1978 (Appendix 1, Table 4).

Accession PI 383309, harvested on the third date, yielded 75 kg of oil per hectare in 1979 (Table 5; and Appendix 1, Table 5). Accession

PI 381609 yielded 61 kg of oil per hectare in 1979. Higher oil yield for accession PI 383309 was because of higher seed weight per capsule than accession PI 381607 in 1979 and in 1978. The higher oil yields of both accessions in 1979 than 1978 were due to higher seed weight per capsule (Table 5) and also higher seed oil content (Appendix 1, Table 10) of the two accessions in 1979 compared to 1978. Both accessions produced fewer number of capsules in 1979 than 1978 (Appendix 1, Tables 4 and 5).

There is very little information on *P. bracteatum* seed oil yield. An average seed yield of 675 kilograms per hectare has been reported for opium poppy (17). Considering the average of 50% oil for the opium poppy seed (31), about 330 kg of oil per hectare would be expected for opium poppy. This is much higher than that obtained for *Papaver bracteatum* in this study.

SUMMARY AND CONCLUSIONS

A field study was conducted to determine the optimum capsule harvest date of accession PI 383309 and PI 381607 of Papaver bracteatum L. to give optimum thebaine yield and seed oil yield while having acceptable seed germination. The effects of pre-storage drying on the yield components and on seed germination were also investigated in the second year of the study. Practicality and economic feasibility for mechanized capsule harvest were considered in determination of optimum harvest date. The possibilities of storing and cleaning of the plant material harvested on different dates were studied when considering the choice of the optimum capsule harvest date.

The study included two harvest periods in two growing seasons: summers of 1978 and 1979. Plants were two years old during the first year of study (1978) while they were three years of age during the second year of the study (1979). Seven harvest dates, with one-week intervals, were studied in both years. All data were statistically analyzed in 1978, using a split-plot design. The two accessions served as main plots, and harvest dates as sub-plots. The effects of pre-storage drying methods on the yield components were included in the study in 1979. Therefore, the data were analyzed as a split-split-plot in 1979, using the pre-storage drying methods as sub-sub-plots. Since the crop is a perennial, year interactions were also studied. In this respect, the data for two accessions were averaged, harvest dates were considered as main plots, years served as sub-plots, and the data were statistically analyzed using a split-plot design.

The first harvest date was four weeks after the poppies were in full bloom. That was on June 21 in both years of the study. The harvested plant materials for the dryer-dried treatments in 1979 were dried immediately after harvesting in a fan-forced air dryer at $40^{0}C$ ($105^{0}F$).

Although the data for the capsule thebaine concentration on different harvest dates in 1978 were found not to be reliable, the data in 1979 showed no significant effects of harvest date on thebaine concentration in the capsules of accession PI 383309. Dryer-dried capsules in 1979 were not analyzed for thebaine. Therefore, the data for the effects of pre-storage drying on the capsule thebaine concentration were not obtained.

Average thebaine concentration for seven harvest dates in the capsules of accession PI 381607 were significantly (.05 level) higher than accession PI 383309 in 1978. Also, average thebaine concentration in the capsules of accession PI 383309 for seven harvest dates in 1978 (when plants were two years old) was significantly (0.05 level) higher than that in 1979 (when plants were three years old). This result does not agree with the idea that thebaine content of the shoots increases with plant age (22). However, that might be true for younger plants (6).

Capsule yield of neither accession was significantly affected by the harvest date in the two years of the study. The effect of pre-storage drying on the capsule yield was merely due to changes in water content of the capsules. Accession PI 383309 produced heavier capsules than accession PI 381607 in 1978, but not in 1979. Both accessions produced significantly (0.01 level) heavier capsules in 1979 than in

1978. However, the number of capsules per plant for both accessions was lower in 1979 than in 1978.

Data obtained for the total thebaine yield of the two accessions in 1978 were not valid. The total capsule thebaine yields of accession PI 383309 were not significantly different for different harvest dates in 1979. However, it was the highest on the third harvest date in this year. Average total thebaine yields of accession PI 383309 for seven harvest dates in 1978 and 1979 were not significantly different. That was because the higher capsule yield of this accession in 1979 was offset by lower thebaine concentration. Average capsule thebaine yield of this accession for seven harvest dates in 1978 (when plants were two years old) was higher than in 1979 (when plants were three years old).

Harvest date significantly (0.01 level) affected the seed yield of the two accessions in both years of the study. However, this effect was more pronounced in 1979 when both accessions produced significantly higher amounts of seed than in 1978. The effect of pre-storage drying on seed yields for different harvest dates was due to the changes in seed water content. Seed yield of accession PI 383309 was higher than that for accession PI 381607 in 1978, but, as was true for capsule yield, this difference between the seed yield of the two accessions diminished in 1979. Seed shattering in both accessions after the third harvest was severe in both years of the study. Selections or breeding of this crop species for shatter-resistant varieties is needed.

Seed oil content of neither accession was significantly affected by harvest date in either year of the study. The effect of pre-storage drying on the oil content of the seeds harvested on different dates was not significant. Seed oil content was the most stable yield component on different harvest dates for both accessions. Oil content of the seeds of accession PI 383309 was significantly (0.01 level) higher than accession PI 381607 in 1978, even though the difference between the seed oil content of the two accessions was very small. However, this difference was not significant in 1979, although the seed oil content of accession PI 383309 was still higher than that for accession PI 381607. Seed oil content of both accession were significantly (0.05 level) higher in 1979 than in 1978.

With the seed oil content very stable on different harvest dates, the effect of harvest date on the total seed oil yield of both accessions was through the changes in seed yield. Harvest date did not significantly affect the total seed oil yield of either accession in 1978. However, seed oil yield of both accessions were significantly (0.01 level) affected by the date of harvest in 1979. The seed oil yield of accession PI 383309 was significantly (0.01 level) higher than accession PI 381607 in 1978. For both accessions, seed oil yield dropped very rapidly after the third harvest date in both years of the study. Seed oil yield of both accessions were significantly (0.01 level) higher in 1979 (when plants were three years old) than in 1978 (when plants were two years old.

The percent seed germination of neither accession harvested on different dates were significantly different in the two years of the study. Also, pre-storage drying of the seeds did not change the percent germination of the seed of either accession significantly in 1979. However, the seeds of later harvest dates germinated faster and more vigorously than dryer-dried seeds. The seed germination percentages for the open-air-dried samples of both accessions were higher than those for dryer-dried samples in 1979. Nevertheless, it was found that the seeds of both accessions were viable since the first harvest date. Further study needs to be done to investigate possible seed dormancy in this plant species.

Finally, it was concluded that the third harvest date is the optimum capsule harvest date under the climatic conditions of the Willamette Valley of Oregon. That date (July 5) was seven weeks after petal opening in both years of the study.

An average of 8 kilograms of thebaine per hectare was obtained by harvesting the capsules (plus 15 cm of attached peduncle) of this crops species seven weeks after petal opening. Thebaine yield of accession PI 383309 in 1979 was a little lower than 8 kg while it was higher than that for accession PI 381607 in 1978. Thebaine yield obtained in this study is significantly lower than that reported by some investigators who harvested the roots of this plant species. However, from the economic point of view, harvest of only capsules of this perennial crop is certainly preferable to the harvest of the roots.

An average yield of about 45 kg of oil per hectare from the seeds of the two accessions was calculated for the capsules harvested on the third date (seven weeks after petal opening) in 1978. This yield averaged about 65 kg of oil per hectare in 1979 when plants were three years old. These yields were notably lower than those previously reported for opium poppy.

Mechanized harvesting of the capsules seemed to be quite feasible on the third harvest date in both years of the study. Capsule moisture content on the third harvest date was low enough that they could be stored without further drying. Seeds were quite ripe and loose in the capsules on that date. Having all these properties on the third harvest date makes it possible to complete all the harvesting processes with a combine.

More studies need to be done to select or breed this plant species for uniformity of flowering and plant height, uprightness of the capsules, and resistance to seed shattering; all the characteristics which are essential for mechanized harvesting of the capsules.

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APPENDICES

APPENDIX I

Table 1. Mean air temperature, mean precipitation, and their deviations from normals during the 1977-78 and 1978-79 crop years at the Hyslop Crop Science Field Laboratory, Corvallis, Oregon.

Year	Month	Mean Air Temperature °C	Deviation from Normal	Mean Precipitation mm	Deviation from Normal
1977	Sept.	15.1	- 1.5	90.9	+ 57.6
	Oct.	12.2	+ 0.44	65.5	- 30.4
	Nov.	6.9	- 0.44	205.9	+ 52.5
	Dec.	6.6	+ 1.6	280.1	+106.6
1978	Jan.	5.5	+ 1.7	186.4	+ 7.1
	Feb.	7.7	+ 1.5	108.7	- 8.8
	Mar.	9.8	4.23	54.6	- 52.0
	Apr.	10.0	- 0.05	114.0	+ 73.4
	May	12.2	- 0.88	91.6	+ 46.7
	June	17.2	+ 1.1	23.8	- 5.3
	July	19.2	+ 0.44	7.3	- 1.0
	Aug.	19.2	+ 0.44	5.9	+ 45.4
	Sept.	15.4	- 1.2	86.3	+ 53
	Oct.	12.1	+ 0.33	24.8	- 7.11
	Nov.	4.3	- 3	79.7	- 73.6
	Dec.	2.3	- 2.6	107.4	- 66
1979	Jan.	- 0.2	- 4	65.2	-114
	Feb.	5.3	- .83	212	+ 94.4
	Mar.	9.1	+ 1.6	73.4	- 33.2
	Apr.	10.1	+ 0.11	74.4	+ 22.3
	May	13.1	- 0.05	53.5	+ 8.6
	June	16.1	+ 0.05	9.6	- 19.5
	July	19.1	+ 0.33	10.9	+ 2.5
	Aug.	18.2	- 0.55	87.8	+ 53.8

Table 2. Percent thebaine (weight-basis) in open-air-dried capsules[1] of accession PI 383309 and PI 381607 for four replications of seven harvest dates in 1978.

Accession	Date of Harvest	Replications 1	2	3	4	$\bar{x}$
PI 383309	6/21	.94	1.80	1.03	.96	1.18
	6/28	1.38	1.50	1.03	.82	1.13
	7/5	1.67	1.02	1.15	1.03	1.12
	7/12	1.10	1.33	.98	1.31	1.18
	7/19	.94	1.09	1.16	1.14	1.08
	7/26	2.54	2.16	1.20	1.11	1.75
	8/2	.82	1.04	1.44	.93	1.05
	$\bar{x}$	1.31	1.42	1.14	1.04	1.22
PI 381607	6/21	1.05	1.06	1.06	.91	1.02
	6/28	1.38	1.07	2.44	1.12	1.50
	7/5	1.10	1.43	1.15	1.34	1.25
	7/12	1.21	1.23	1.23	1.21	1.22
	7/19	1.26	1.30	1.53	1.05	1.28
	7/26	2.56	3.43	1.04	1.01	2.01
	8/2	1.30	1.23	.80	1.21	1.13
	$\bar{x}$	1.41	1.53	1.32	1.12	1.34

[1]Along with 15 cm of stem (peduncle).

Table 3. Percent thebaine (weight-basis) in dryer-dried capsules[1] of accession PI 383309 for four replications and seven harvest dates in 1979.

Date of Harvest	Replications				
	1	2	3	4	$\bar{X}$
6/21	1.07	1.06	1.06	1.08	1.06
6/28	1.09	1.07	1.07	1.05	1.07
7/5	1.15	1.19	1.08	1.05	1.11
7/12	1.07	1.04	1.17	1.07	1.08
7/19	1.13	1.09	1.09	1.09	1.10
7/28	1.10	1.09	1.08	1.08	1.08
8/2	1.08	1.09	1.09	1.09	1.08
$\bar{x}$	1.09	1.09	1.09	1.07	1.08

[1]Along with 15 cm of stem (peduncle).

Table 4. Average[1] total capsule[2] weight (g), capsule number and weight per capsule[2] (g) of <u>Papaver bracteatum</u> accessions PI 383309 and PI 381607 for seven harvest dates and open-air-dried in 1978, and their means.[3]

Accession	Measurements	Harvest Dates 6/21	6/28	7/5	7/12	7/19	7/26	8/2	$\bar{x}$
PI 383309	Total capsule weight (g)	501	450	463	508	533	416	440	473
	Capsule number	206	177	182	196	197	160	177	185
	Wt/capsule (g)	2.43	2.54	2.54	2.59	2.70	2.60	2.48	2.55
PI 381607	Total capsule weight (g)	494	455	547	434	533	495	369	475
	Capsule number	206	188	219	181	205	202	161	194
	Wt/capsule (g)	2.39	2.42	2.49	2.39	2.60	2.45	2.29	2.43

[1]Average of four replications on a plot area basis.

[2]Along with 15 cm of stem (peduncle).

[3]All the numbers and the means were rounded to the closest number.

Table 5. Average[1] total capsule[2] weight (g), capsule number, and weight per capsule[2](g) of *Papaver bracteatum* accessions PI 383309 and PI 381607 for seven harvest dates and open-air-dried samples in 1979, and their means.[3]

Accession	Measurements	Harvest Dates 6/21	6/28	7/5	7/12	7/19	7/26	8/2	$\bar{x}$
PI 383309	Total capsule weight (g)	220	236	269	240	239	262	242	244
	Capsule number	78	88	104	85	82	97	87	88
	Wt/capsule (g)	2.82	2.68	2.58	2.82	2.91	2.70	2.78	2.77
PI 381607	Total capsule weight (g)	214	263	211	233	242	197	192	221
	Capsule number	80	92	74	87	83	69	70	79
	Wt/capsule (g)	2.67	2.85	2.85	2.67	2.91	2.85	2.74	2.79

[1]Average of four replications on a plot area basis.

[2]Along with 15 cm of stem (peduncle).

[3]All the numbers and the means were rounded to the closest number.

Table 6. Average[1] total capsule[2] weight (g), capsule number, and weight per capsule[2] (g) of *Papaver bracteatum* accessions PI 383309 and PI 381607 for seven harvest dates and dryer-dried samples in 1979, and their means.[3]

		Harvest Dates							
Accession	Measurements	6/21	6/28	7/5	7/12	7/19	7/26	8/2	$\bar{x}$
PI 383309	Total capsule weight (g)	204	208	247	252	231	232	272	235
	Capsule number	75	75	92	91	98	93	104	90
	Wt/capsule (g)	2.72	2.77	2.68	2.76	2.35	2.49	2.61	2.62
PI 381607	Total capsule weight (g)	191	229	203	210	221	281	169	214
	Capsule number	85	89	79	83	82	98	72	84
	Wt/capsule (g)	2.24	2.57	2.56	2.53	2.69	2.86	2.34	2.54

[1]Average of four replications on a plot area basis.

[2]Along with 15 cm of stem (peduncle).

[3]All the numbers and the means were rounded to the closest number.

Table 7. Average[1] total seed weight (g), capsule number, and seed weight per capsule (g) of Papaver bracteatum accessions PI 383309 and PI 381607 for seven harvest dates and open-air-dried in 1978, and their means.[2]

Accession	Measurements	Harvest Dates							
		6/21	6/28	7/5	7/12	7/19	7/26	8/2	$\bar{x}$
PI 383309	Total seed weight (g)	73	67	76	75	70	43	47	64
	Capsule number	206	177	182	196	197	160	177	185
	Seed wt/capsule (g)	.354	.378	.417	.382	.355	.268	.265	.345
PI 381607	Total seed weight (g)	65	59	76	47	57	49	36	55
	Capsule number	206	188	219	181	205	202	161	194
	Seed wt/capsule (g)	.315	.313	.347	.259	.278	.242	.223	.282

[1]Average of four replications on a plot area basis.

[2]All the numbers and the means were rounded to the closest number.

Table 8. Average[1] total seed seight (g), capsule number, and seed weight per capsule (g) of *Papaver bracteatum* accessions PI 383309 and PI 381607 for seven harvest dates and open-air-dried in 1979, and their means.[2]

Accession	Measurements	Harvest Dates							
		6/21	6/28	7/5	7/12	7/19	7/26	8/2	$\bar{x}$
PI 383309	Total seed weight (g)	62	62	70	58	33	32	31	50
	Capsule number	78	88	104	85	82	97	87	88
	Seed wt/capsule (g)	.794	.704	.673	.682	.402	.329	.356	.568
PI 381607	Total seed weight (g)	51	70	46	40	36	20	17	49
	Capsule number	80	92	74	87	83	69	70	79
	Seed wt/capsule (g)	.637	.760	.621	.459	.433	.289	.242	.492

[1]Average of four replications on a plot area basis.

[2]All the numbers and the means were rounded to the closest number.

Table 9. Average[1] total seed weight (g), capsule number, and seed weight per capsule (g) of *Papaver bracteatum* accessions PI 383309 and PI 381607 for seven harvest dates and dryer-dried samples in 1979, and their means.[2]

Accession	Measurements	Harvest Dates 6/21	6/28	7/5	7/12	7/19	7/26	8/2	$\bar{x}$
PI 383309	Seed total weight (g)	51	56	61	60	31	29	44	47
	Capsule number	75	75	92	91	98	93	104	90
	Seed wt/capsule (g)	.680	.746	.663	.659	.316	.311	.423	.522
PI 381607	Total seed weight (g)	50	50	37	36	21	25	12	33
	Capsule number	85	89	79	83	82	98	72	84
	Seed wt/capsule (g)	.588	.561	.468	.433	.256	.255	.166	.392

[1]Average of four replications on a plot area basis.

[2]All the numbers and the means were rounded to the closest number.

Table 10. Average[1] percent oil content[2] of seeds of *Papaver bracteatum* accessions PI 383309 and PI 381607 for seven harvest dates and their means[3] for one drying method in 1978 and two drying methods in 1979

Year	Accession	Harvest Dates 6/21	6/28	7/5	7/12	7/19	7/26	8/2	$\bar{x}$[4]
1978 Open-air-dried	PI 381607	45.72	46.10	46.27	47.02	46.55	46.80	46.25	46.33
	PI 381607	45.77	45.87	45.7	45.32	45.92	45.47	46.20	45.75
1979	PI 383309								
	Open-air-dried	46.12	47.70	46.90	48.11	47.80	48.00	47.57	47.74
	Dryer-dried	48.66	47.31	47.82	47.79	47.71	48.28	48.51	48.02
	$\bar{x}$	47.39	47.51	47.36	47.95	47.76	48.14	48.05	47.88
	PI 381607								
	Open-air-dried	46.82	47.11	47.32	47.71	47.00	47.08	46.95	47.14
	Dryer-dried	47.92	46.46	46.48	46.08	47.05	46.39	47.03	46.77
	$\bar{x}$	47.37	46.79	46.90	46.90	47.03	46.74	46.99	46.96

[1]Average of four replications on a plot area basis.

[2]Percent of oven dry seed weight.

[3]All the numbers and the means were rounded to the closest number.

[4]Numbers beside a continuous line are not significantly different at the .05 level.

Table 11. Average[1] percent seed germination of *Papaver bracteatum* accessions PI 383309 and PI 381607 for seven harvest dates for one drying method in 1978 and two drying methods in 1979, and their means.[2]

Year	Accession	Harvest Dates							
		6/21	6/28	7/5	7/12	7/19	7/26	8/2	$\bar{x}$
1978 Open-air-dried samples	PI 383309	80	74	84	82	83	77	87	81
	PI 381607	85	82	85	87	85	72	82	83
	$\bar{x}$	82	78	84	84	84	74	84	82
1979 Open-air-dried samples	PI 383309	78	74	81	83	81	73	77	78
	PI 381607	72	81	68	68	77	72	80	74
	$\bar{x}$	75	77	74	75	79	72	78	76
1979 Dryer-dried samples	PI 383309	65	72	71	66	69	78	82	72
	PI 381607	60	75	77	67	75	77	75	72
	$\bar{x}$	64	73	74	66	72	77	78	72

[1]Average of four replications on a plot area basis.

[2]All the numbers and the means were rounded to the closest number.

APPENDIX II

Table 1. Analysis of variance for percent thebaine on a dry weight basis, of open-air-dried capsules[1] of Papaver bracteatum accessions PI 383309 and PI 381607 harvested on seven dates in 1978, and their interactions.

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	0.4061	59.877**
Accessions	1	0.1945	28.602*
Error (a)	3	0.0068	
Harvest date	6	0.5963	2.862*
Harvest x accession	6	0.0612	0.293
Error (b)	36	0.2083	
Total	55		

*Significant at 0.05 level
**Significant at 0.01 level
L.S.D. for harvest dates (0.05 level) = .655 (when comparing the means for each accession).
L.S.D. for harvest dates (0.05 level) = .463 (when comparing the means for the average of the two accessions).

Table 2. Analysis of variance for percent thebaine on a dry weight basis, of dryer-dried capsules[1] of Papaver bracteatum accession PI 383309, harvested on seven dates in 1979.

Source of Variation	Degrees of Freedom	Mean Square	F
Replications	3	0.00085	0.70530 NS
Harvest date	6	0.00118	0.97208 NS
Error	18	0.00122	
Total	27		

NS = Not significant
[1]Along with 15 cm of stem (peduncle)

Table 3. Analysis of variance for weight per capsule[1] (g) of *Papaver bracteatum* accessions PI 38309 and PI 381607, harvested on seven dates and open-air-dried in 1978, and their interactions.

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	0.1139	1.279 NS
Accessions	1	0.1830	2.056 NS
Error (a)	3	0.0890	
Harvest date	6	0.0746	1.217 NS
Harvest x accession	6	0.0082	0.123 NS
Error (b)	36	0.0613	
Total	55		

NS = Not significant
[1]Along with 15 cm of stem (peduncle)

Table 4. Analysis of variance for weight per capsule[1] (g) of <u>Papaver bracteatum</u> accessions PI 38309 and PI 381607, harvested on seven dates in 1979 and dried with two methods, and their interactions.

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	0.15187	0.5217
Accessions (Acc)	1	0.03975	0.1365
Error (a)	3	0.29103	
Harvest dates (Har)	6	0.03817	0.4040
Har x Acc	6	0.13830	1.4041
Error (b)	36	0.09446	
Drying methods	1	0.61272	11.0699**
Method x Acc	1	0.11636	2.1022
Method x Har	6	0.12101	2.1862
Method x Har x Acc	6	0.13536	2.4455*
Error (c)	42	0.05535	
Total	111		

**Significant at 0.01 level
*Significant at 0.05 level
[1]Along with 15 cm of stem (peduncle)

Table 5. Analysis of variance for percent thebaine on a dry weight basis, of capsules[1] of Papaver bracteatum accession PI 383309, harvested on seven dates in 1978 (open-air-dried) and 1979 (dryer-dried), and their interactions (years were considered as subplots).

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	0.1086	1.7102
Harvest dates	6	0.1113	1.7527
Error (a)	17	0.0635	
Year	1	0.3271	4.9635*
Year x harvest dates	6	0.1106	1.5913
Error (b)	21	0.0695	
Total	55		

*Significant at 0.05 level
[1]Along with 15 cm of stem (peduncle)

Table 6. Analysis of variance for weight per capsule[1] (g) for the average of Papaver bracteatum accessions PI 38309 and PI 381607, harvested on seven dates and open-air-dried in 1978 and 1979, and their interactions (years were considered as subplots).

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	0.0408	1.059
Harvest dates	6	0.0405	1.051
Error (a)	18	0.0385	
Year	1	1.0149	22.063**
Year x harvest dates	6	0.0201	0.436
Error (b)	21	0.0460	
Total	55		

**Significant at 0.01 level.
[1]Along with 15 cm of stem (peduncle)

Table 7. Analysis of variance for total thebaine yield (g/100 capsules[1]) of Papaver bracteatum accessions PI 383309 and PI 381607, harvested on seven dates in 1978, and open-air-dried, and their interactions.

Source of Variation	Degrees of Freedom	Mean Square	F
Replications	3	2.6788	19.668*
Accessions	1	0.5226	3.837
Error (a)	3	0.1362	
Harvest date	6	4.0864	3.231*
Harvest x accession	6	0.4450	0.351
Error (b)	36	1.2645	
Total	55		

*Significant at 0.05 level.

L.S.D. for harvest dates (0.05 level) = 1.614 (when comparing the means for each accession).

L.S.D. for harvest date (0.05 level) = 1.141 (when comparing the means for the average of the two accessions).

[1]Along with 15 cm of stem (peduncle)

Table 8. Analysis of variance for total thebaine yield (g/100 capsules[1]) of Papaver bracteatum accession PI 383309, harvested on seven dates and dryer-dried in 1979.

Source of Variation	Degrees of Freedom	Mean Square	F
Replications	3	.033	0.38 NS
Harvest dates	6	.105	1.22 NS
Error	18	.086	
Total	27		

NS = Not significant

[1]Along with 15 cm of stem (peduncle)

Table 9. Analysis of variance for total thebaine yield (g/100 capsules[1]) of Papaver bracteatum accession PI 383309, harvested on seven dates in 1978 (open-air-dried) and 1979 (dryer-dried), and their interactions (years were considered as subplots).

Source of Variation	Degrees of Freedom	Mean Square	F
Replications	3	0.6404	1.8375 NS
Harvest date	6	0.6235	1.7890 NS
Error (a)	18	0.3485	
Year	1	1.4464	2.8261 NS
Year x harvest	6	0.9217	1.8008 NS
Error (b)	21	0.5118	
Total	55		

NS = Not significant
[1]Along with 15 cm of stem (peduncle)

Table 10. Analysis of variance for seed weight per capsule (g) of Papaver bracteatum accessions PI 383309 and PI 381607 harvested on seven dates in 1978 and open-air-dried, and their interactions.

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	0.0086	2.0476
Accessions	1	0.0403	9.5952
Error (a)	3	0.0042	
Harvest date	6	0.0171	33.5294**
Harvest x accession	6	0.0025	0.4901
Error (b)	36	0.0051	
Total	55		

**Significant at 0.01 level
L.S.D. (0.01 level) = .137
L.S.D. (0.05 level) = .102

Table 11. Analysis of variance for seed weight per capsule (g) of *Papaver bracteatum* accessions PI 383309 and PI 381607, harvested on seven dates and dried with two methods in 1979, and their interactions.

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	0.07354	1.0827
Accessions (acc)	1	0.34078	5.1073
Error (a)	3	0.06792	
Harvest date (Har)	6	0.55467	56.4262**
Har x acc	6	0.01221	1.2412
Error (b)	36	0.00983	
Drying method	1	0.09606	9.7128**
Method x acc	1	0.02036	2.0586
Method x har	6	0.00802	0.8109
Method x har x acc	6	0.01231	1.2446
Error (c)	42	0.00989	
Total	111		

**Significant at 0.01 level
L.S.D. for harvest dates (0.01 level) = .190
L.S.D. for harvest dates (0.05 level) = .142

Table 12. Analysis of variance for oil content of seed (percent oven-dry basis) of Papaver bracteatum accessions PI 383309 and PI 381607, harvested on seven dates and open-air-dried in 1978, and their interactions.

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	2.1614	23.570*
Accessions	1	5.6578	61.699**
Error (a)	3	0.0917	
Harvest date	6	0.2449	0.3238
Harvest x accession	6	0.8645	1.1433
Error (b)	36	0.7561	
Total	55		

*Significant at 0.05 level
**Significant at 0.01 level

Table 13. Analysis of variance for oil content of seed (percent oven-dry basis) of Papaver bracteatum accessions PI 383309 and PI 381607, harvested on seven dates and dried with two methods in 1979, and their interactions.

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	2.05175	0.28178 NS
Accessions (Acc)	1	1.46972	0.20184 NS
Error (a)	3	7.28127	
Harvest date (Har)	6	1.46972	0.17065 NS
Har x Acc	6	6.60807	0.76728 NS
Error (b)	36	8.61232	
Drying method	1	0.06557	0.01110 NS
Method x Acc	1	4.08511	0.60292 NS
Method x Har	6	6.73202	1.14041 NS
Method x Har x Acc	6	11.41070	1.93290 NS
Error (c)	42	5.90314	
Total	111		

NS = Not significant

Table 14. Analysis of variance for seed weight per capsule (g) for average of Papaver bracteatum accessions PI 383309 and PI 381607, harvested on seven dates and open-air-dried in 1978 and 1979, and their interactions (years were considered as subplots).

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	0.0205	6.612**
Harvest dates	6	0.1067	34.419**
Error (a)	18	0.0031	
Year	1	0.6444	140.000**
Year x harvest date	6	0.0487	10.556**
Error (b)	21	0.0046	
Total	55		

**Significant at 0.01 level.

Table 15. Analysis of variance for oil content of seed (percent oven-dry basis) of Papaver bracteatum accession PI 383309 and PI 381607 for average of seven harvest dates in 1978 and average of seven harvest dates and two drying methods in 1979, and their interactions (years were considered as subplots).

Source of Variations	Degrees of Freedom	Mean Square	F
Replicatons	3	0.1278	0.480
Accessions	1	0.7482	2.814
Error (a)	3	0.2658	
Year	1	3.7249	12.346*
Year x accessions	1	0.1640	0.543
Error (b)	6	0.3017	
Total	15		

*Significant at 0.05 level.

Table 16. Analysis of variance for total seed oil yield (g/100 capsules) of *Papaver bracteatum* accessions PI 383309 and PI 381607, harvested on seven dates in 1978 and open-air-dried, and their interactions.

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	32.2590	4.880
Accessions	1	112.9752	17.091*
Error (a)	3	6.6102	
Harvest date	6	29.3929	2.103
Harvest x accession	6	4.2456	0.303
Error (b)	36	13.9733	
Total	55		

*Significant at 0.05 level.

Table 17. Analysis of variance for total seed oil yield (g/100 capsule) of *Papaver bracteatum* accessions PI 383309 and PI 381607, harvested on seven dates in 1979 and open-air-dried, and their interactions.

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	106.6703	1.208
Accessions	1	276.1236	3.127
Error (a)	3	88.2866	
Harvest date	6	636.0953	25.697**
Harvest x accession	6	46.6098	1.883
Error (b)	36	24.7540	
Total	55		

**Significant at 0.01 level.
L.S.D. (0.01 level) = 9.58
L.S.D. (0.05 level) = 7.14

Table 18. Analysis of variance for total seed oil yield (g/100 capsules) for the average of Papaver bracteatum accessions PI 383309 and PI 381607, harvested on seven dates and open-air-dried in 1978 and 1979, and their interactions (years were considered as subplots).

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	92.7099	7.490**
Harvest date	6	171.5781	13.863**
Error (a)	18	12.3765	
Year	1	1740.0690	122.136**
Year x harvest date	6	86.5842	6.077**
Error (b)	21	14.2464	
Total	55		

**Significant at 0.01 level.

Table 19. Analysis of variance for percent seed germination of Papaver bracteatum accessions PI 383309 and PI 381607, harvested on seven dates in 1978, and their interactions.

Source of Variations	Degrees of Freedom	Mean Squares	F
Replications	3	35.2083	0.1880 NS
Accessions	1	27.1607	0.1450 NS
Error (a)	3	187.2083	
Harvest date	6	123.1250	1.9717 NS
Harvest x accession	6	53.1607	.8513 NS
Error (b)	36	62.4444	
Total	55		

NS = Not significant

Table 20. Analysis of variance for percent seed germination of *Papaver bracteatum* accessions PI 383309 and PI 381607, harvested on seven dates and dried with two methods in 1979, and their interactions.

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	434.889	1.745 NS
Accessions (Acc)	1	91.080	.365 NS
Error (a)	3	249.223	
Harvest date (Har)	6	166.434	.730 NS
Har x Acc	6	72.892	.320 NS
Error (b)	36	227.834	
Drying methods	1	510.008	3.280 NS
Method x Acc	1	84.008	.540 NS
Method x Har	6	107.113	.688 NS
Method x Har x Acc	6	117.821	.757 NS
Error (c)	42	155.473	
Total	111		

NS = Not significant

Table 21. Analysis of variance for percent seed germination for the average of Papaver bracteatum accessions PI 383309 and PI 381607, harvested on seven dates in 1978 (open-air-dried) and 1979 (average for two drying methods), and their interactions (years were considered as subplots).

Source of Variations	Degrees of Freedom	Mean Square	F
Replications	3	231.589	2.620
Harvest dates	6	77.279	0.874
Error (a)	18	88.367	
Year	1	1107.160	0.590**
Year x harvest date	6	105.494	0.913
Error (b)	21	115.446	
Total	55		

**Significant at the 0.01 level.