NUTRITIONAL AND TIME OF HARVESTING STUDIES OF THE POPPY (*Papaver somniferum* L.) ON KRASNOZEM SOILS OF TASMANIA

Nutritional and Time of Harvesting Studies of *Papaver somniferum* L.

by

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This thesis contains no material which has been accepted for the award of any other degree or diploma in any University, and to the best of my knowledge contains no copy or paraphrase of material previously published or written by any other persons except where due reference is made in the text of the thesis.

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December, 1977.

Nec non et lini segetem et Cereale papaver
tempus humo tegere et iamdudum incumbere aratris,
dum sicca tellure licet, dum nubila pendent (I 212)
Post, ubi nona suos Aurora ostenderit ortus,
inferias Orphei Lethoea papavera mittes
et nigram mactabis ovem lucumque revises. (IV 544)

Virgil-Georgics

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SUMMARY

The effects of banded nitrogen and phosphorus fertilizer on the growth of poppies on a krasnozem soil were studied at three different stages of growth; (i) young plants fifty days after sowing (ii) mature capsules at dry commercial maturity eight weeks after full bloom, (iii) total plant and its components harvested at weekly intervals between full bloom and dry commercial maturity.

Higher uptake of banded P and greater plant dry matter yield 50 days after sowing were recorded when the fertilizer was placed 40 mm directly below the seed than when placed 75 mm below. Nitrogen had a negative effect on both uptake and yield in this experiment.

At dry commercial maturity N X P interaction effects were recorded for capsule, seed and morphine yields. The pattern of yields giving these interactions was a lack of response to N at zero and low to medium rates of P (0 to 40 kg/ha) and a marked positive response to N at high levels of P (90 kg/ha and greater). Between flowering and dry maturity, N X P interaction effects were also shown at all times of harvest for total plant, lateral capsules and stem and leaves. Terminal capsules were an exception and the yield of this component was depressed by P and yield of seed from terminal capsules was also depressed by N and P particularly at the time of dry commercial maturity.

Broadcast and uniformly mixed $Ca(OH)_2$ gave maximum yields of capsule and seed at a rate of 25 t/ha and a bulk soil pH of 8.1. However banded N P fertilizer near the seed probably modified local pH and high yields were associated with high tissue levels of magnesium, sodium, molybdenum and copper.

The concentration and yield of morphine in the capsules and stem and leaves was measured between flowering and maturity. Morphine concentration gradually built up to a maximum at about six weeks after full

bloom and then fell in all components. In contrast to morphine the dry matter yields of all plant components except seed reached their maxima about two weeks after full bloom and then declined successively towards dry commercial harvest about eight weeks after full bloom. Seed yield achieved a maximum value about one month after full bloom and remained constant. The mutually compensating factors of decreasing dry matter yield and increasing morphine concentration gave similar total plant morphine yields at any time of harvest from two to six weeks after full bloom. The harvest of whole plants thus gave 55% higher morphine yield than mature dry capsules alone. Capsules harvested semi-dry two weeks prior to commercial harvest gave 18% greater morphine than capsules at commercial maturity.

Simulated leaching experiments suggested that morphine could be lost from dry capsules by this means but also suggested that morphine breakdown occurred within the capsule wall.

An association was shown between high fungal infection and low capsule morphine in the field and this was confirmed by artificial inoculation. Helminthosporium papaveris, Alternaria alternata and Cladosporium herbarum were identified on capsules but a regular application of mancozeb and benlate from petal fall failed to control their development. Fungi were isolated from capsules less than three weeks after full bloom. However the spray schedule increased the dry matter yield of capsules and stem and leaves.

1. LITERATURE REVIEW

1.1. Introduction

The poppy plant (Papaver somniferum L.) has been cultivated as a crop of economic importance for at least 5000 years (Neligan 1927). Initially it is likely that it was grown in the Middle Eastern region of the northern hemisphere for its seed which is high in both oil (50%) and protein (Neligan 1927). However it is also clear that the medicinal and narcotic properties of opium or air dried latex containing the poppy alkaloids were known at least 2000 years ago (Kritikos and Papadaki 1967).

Where Papaver somniferum is grown for opium production it is referred to as the "opium" poppy. However when grown for the dual purpose use of alkaloid extraction and seed production or seed production only it is often designated as the "oil" poppy. Poppy seed is extensively used for culinary purposes, in baking and as a stock feed ("maw" seed), while poppy seed oil is used as a salad oil for margarine manufacture, in paint manufacture, in varnishes and perfumes. The distinctions between the two designations hinge on cultivar and ecotype selection. In Europe generally the production of seed for culinary purposes is the more important facet of production and this is particularly so in the cuisines of the East European countries. However in 1927 it was shown by the Hungarian chemist Johann Kabay that morphine could be economically extracted from the mature dry poppy capsule or poppy "straw" as it was termed (Bayer 1961). Since then the dual purpose use of the crop as a source of seed and plant alkaloids has been practised in many of the European poppy growing areas.

1.2. The Cultivation of Papaver somniferum in Australia

Although the poppy had been grown as an ornamental for many years and the possibility of its commercial production was canvassed in New

South Wales in the 19th century (Turner 1891) it was not until World War II that shortages of medicinal drugs prompted experimental work in the Canberra district (Loftus Hills 1945). In addition field observational trials on the adaptation of cultivars were carried out by the Tasmanian Department of Agriculture during World War II along with some preliminary bulking up of poppy straw (Walker, Personal Communication).

After World War II no further experimental work with P. somniferum was undertaken in Tasmania until 1960. At this time a research programme was initiated to explore various cultural aspects of poppy production in the state. Commercial production was commenced in 1969 using the technique of harvesting mature dry capsules, extracting alkaloids from the capsules and marketing seed as well. (Allen and Frappell 1970). In the 1976/77 season a total area of 7000 hectares was sown. The crop is grown on private farms under a contract system which is operated by two commercial companies who also carry out the extraction of alkaloids. Initially morphine is extracted and this is utilised as such by the pharmaceutical industry but the bulk of the morphine is converted to codeine.

The overall operation of the commercial production and utilisation of P. somniferum is covered by the requirements of the Tasmanian Poisons Act 1971 (Act No. 81) and Tasmania is an approved signatory of the United Nations Convention of 1961 which sets out the requirements for the legal cultivation of P. somniferum. Because of a Commonwealth Agricultural Council agreement between the Australian states the cultivation of P. somniferum is restricted exclusively to Tasmania.

1.3. Morphology and Ecological Variation

Detailed descriptionsof the morphology and climatic range of Papaver Somniferum have been given by Fulton (1944) and Vesselovskaya (1933). Although the plant covers a wide geographical range with considerable

variability in flowers, seed and capsule, there is nevertheless a general appearance which is characteristic and easily recognisable.

The brief description given by Curtis and Morris (1975) is useful as a general guide ..... "An annual herb with erect stem, simple or branched, 20 - 100 cm high. Leaves toothed or pinnately lobed, the lower ones shortly stalked, the upper sessile and stem clasping, glaucous, glabrous or with some stiff hairs. Petals pinkish-lilac usually with a dark blotch at the base. Capsule dehiscent or indehiscent, globular or ovoid, 1.5 - 2.5 cm long, glabrous, the stigmatic disc with 7 - 15 stigma rays and deep marginal lobes."

This description can be modified by the facts that the plant can be up to 150 cm tall and the flowers of P. somniferum can be single or double with considerable variation in shape and colour of petals which can be white, pink, red, purple, crimson, violet or variegated. Seeds may also be white, yellow, brownish, black, grey, blue or violet (United Nations Report 1967).

The ecological-geographical variation within the species has been studied by Vesselouskaya (1933) who classified the range from sub-tropics to Northern European in the following way: (i) Sub-tropical or Indian, (ii) Southern - Persian and Afghan, (iii) Turkish, (iv) Tian - Shanian - Kirghizstan, (v) Mongolian, (vi) Central Asiatic - Zungaria and Kazakhstan, (vii) Northern.

The most important requirements for each of these ecotypes were day length and rainfall.

1.4. Anatomy and Physiology

Papaver somniferum is the only species of the Papaveraceae which produces morphine and this includes the arguably classified sub species Papaver somniferum ssp. setigerum (D.C.) Corb. Although at least twenty five other alkaloids are also produced, morphine and codeine

make up fifteen to twenty percent of the total and are by far the most important commercially. These alkaloids occur primarily in the latex which is found only in specialised laticiferous vessels. Esau (1953 and 1962) concluded that in the genus Papaver the laticiferous vessels or laticifers are developed from single vertical rows of cells in which the horizontal end walls are absorbed. At a later stage lateral anastomoses develop which join up with neighbouring tubes and hence an articulated anastomosing system of latex vessels is produced. Laticifers occur in the root and stem and are particularly abundant in the capsules of the poppy. They are exclusively restricted to the phloem and are never in direct contact with xylem vessels (Fairbairn and Kapoor 1960) (Fig.1). Fairbairn and Kapoor found that laticifers could be distinguished from surrounding phloem cells by (i) their generally oval outline and larger diameter of 20 to 30 μ compared to 10 to 13 μ for sieve tubes and (ii) their slightly thickened and highly refractive walls.

Comparative anatomical studies of opium and oil poppy selections have shown that the opium poppy has more numerous latex vessels of a larger diameter (Aleksandrov and Visloukh 1934; Aleksandrov and Aleksandrova 1932). In addition the opium poppy capsule commonly has thicker walls and a more prolific latex flow when incised (Shulgin 1969).

Latex vessels pass into the sepals and petals but are not present in the stamens, ovules or seeds (Fairbairn and Kapoor 1960). Mika (1955) concluded likewise that laticifers were absent from stamens, ovules and seeds but that they developed in young seedlings when the first true leaves formed.

The fact that the alkaloids of P. somniferum are restricted to specialised latex vessels contrasts with the pattern found in many other

plants which also produce alkaloids. Thus in Atropa, Nicotiana and Datura species the alkaloids occur in non-specialised living cells, especially those where the metabolic activity is high such as shoot and root apices (James 1953). But although the laticifers are highly specialised storage tissue they are not merely "drain pipes" or storage organs. In P. somniferum they also have the capacity to both synthesise morphine from its precursors and break down some of the morphine once formed (See 1. 6.4).

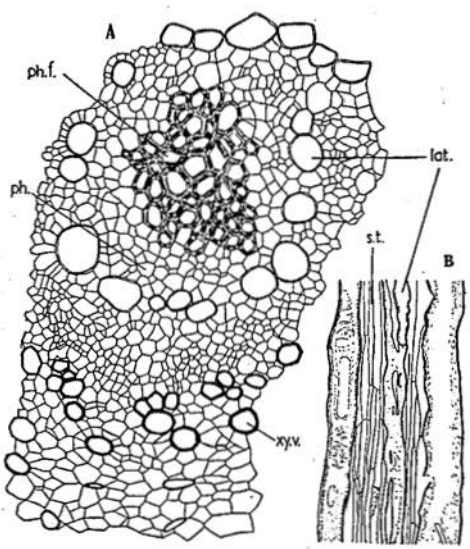


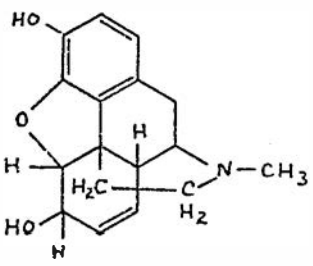
Fig. 5: Central bundle of pedicel. (×200). *A.* in transverse section. *B.* in radial longitudinal section. *lat.* laticifer. *ph.* phloem. *ph.f.* phloem fibres. *s.t.* sieve tube. *xy. v.* xylem vessel.

Fig. 1. Vascular bundle of pedicel showing the relationship between laticifers and surrounding tissue (From Fairbairn J.W. and Kapoor L.D. 1960).

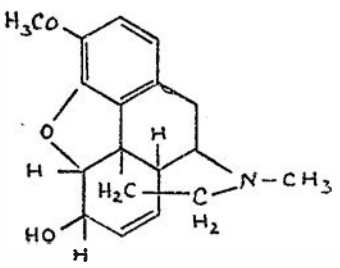
1.5. The Alkaloids of Papaver somniferum

The latex of P. somniferum contains at least twenty five alkaloids of which morphine, codeine thebaine, narceine, narcotine and papaverine are the most important. Morphine forms 9 to 17% of the total alkaloid complex and makes up 0.1 to 1.0% of the dry matter of the capsule depending on cultivar and season (Pfeifer 1962).

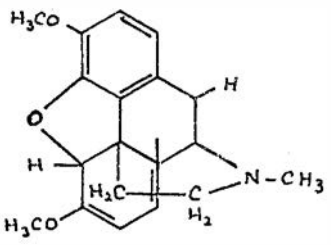
Alkaloids may be briefly defined as nitrogenous organic bases which occur naturally in plants (Swan 1967) and the structural formulae of the six main alkaloids of P. somniferum are set out below.



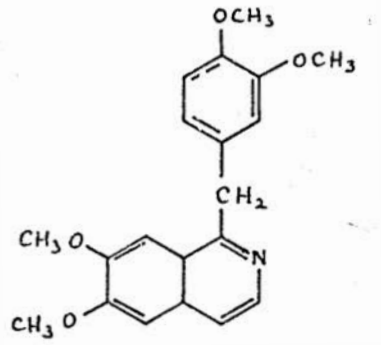
Morphine



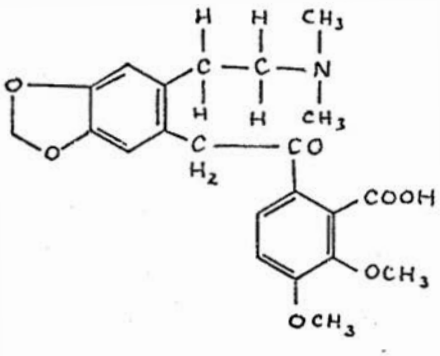
Codeine



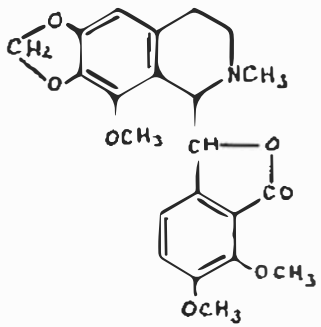
Thebaine



Papaverine



Narceine



Narcotine

1.6. Time of Harvesting

1.6.1 Ontogenetic Changes in Plant Components

The yield of morphine from any of the poppy plant components is the product of dry matter x morphine concentration. Hence a consideration of the effect of time of harvesting must include changes in both dry matter and morphine concentration over time.

1.6.1.1 Dry Matter

In a very detailed study, Nikonov (1958) working with opium cultivars in the Soviet Republic of Kirghizia found an increase in total plant dry weight right up to dry harvest maturity. In this experiment the only individual plant components which decreased in dry matter yield were the leaves. Other workers have found different patterns of dry matter change to that of Nikonov. The general trend was for dry weight of capsules, stem and leaves to reach a maximum yield about two weeks after petal fall and then decline up to dry harvest maturity. For capsules Kuhn (1936) in Czechoslovakia and Loftus Hills (1945) in the Australian Capital Territory both recorded decreases of 10% in dry weight compared to the maxima previously achieved. In a very detailed study of the capsules of P. somniferum over a number of years Bunting (1963) found similarly that the decrease was 10 - 15% for a range of cultivars grown in southern England. In Bunting's experiments the maximum dry weight of capsules occurred 16 - 21 days after flowering when the dry matter content was only 16 - 20%. In the reports of Kuhn (1936) and Loftus Hills (1945) only visual descriptions of stages of development were given but maximum dry weight appeared to occur at about the same time as that defined by Bunting (1963).

In East Germany a number of experimenters have studied dry matter changes of the total plant and some of the individual components (Romisch 1958, Heeger and Schroder 1959, Pfeifer and Heydonreich 1962).

Keeger and Schroder found that maximum total plant dry matter yield occurred at the half -ripe stage about one month after flowering and that at dry harvest maturity yields were 10 - 15% less than the previous maximum. Pfeifer and Heydenreich found maximum dry matter yield of total plant at two to three weeks after flowering for a range of cultivars and that the yield at dry maturity was 16% less than the maximum. Romisch obtained much greater dry matter yield decreases for the same comparisons and at dry harvest the total plant dry matter yields of two cultivars were 40% and 33% less than their previous maxima.

Changes in dry matter of the seeds of P. somniferum between flowering and maturity have not been studied in detail except for the work of Bunting (1963). Bunting determined the moisture contents over a number of periodic harvests and concluded that maximum dry matter was attained about four weeks after full bloom at a dry matter content of 50%.

1.6.1.2. Morphine Concentration

Reports on the pattern of morphine accumulation in capsules have shown large differences. Nikonov (1958) showed that capsule morphine concentration increased right up to dry maturity. Miram and Pfeifer (1959) and Heeger and Schroder (1959) also reported steady increases. In contrast to this pattern a number of other authors have shown that the levels build up to a maximum when the capsules are green or semi-ripe and then decline towards dry commercial maturity (Poethke and Arnold 1951, Wegner 1951, Bunting 1963, Schroder 1965). Loftus Hills (1945) in his measurement of morphine concentration of capsules found small changes only during the ripening of capsules in two out of three seasons.

The most detailed of these studies of morphine changes in capsules has been that of Bunting (1963). He concluded from investigation of a number of cultivars over a range of seasons that under the conditions of

southern England the levels in capsules built up to a maximum 37 - 40 days after flowering and then declined. The pattern was similar for different cultivars but varied widely between seasons.

The pattern of morphine concentration changes in the total plant is generally that the levels are greatest during the green or semi-dry phase and then decline towards dry harvest maturity. Heeger and Schroder (1959) found that at dry maturity the concentration was 30% less than four weeks earlier while Romisch (1958) found total plant morphine concentrations at dry maturity were halved over the same period.

1.6.2. The Effect of Leaching on Plant Morphine

Poppy capsules are commonly harvested when their dry matter content is about 85 - 90%. However if harvest is delayed by the onset of wet or overcast conditions capsule morphine concentrations will commonly fall. Several authors have attributed this fall to the leaching of morphine from the capsules (Loftus Hills 1945, Foethke and Arnold 1951, Bunting 1963). A significant reduction in morphine concentration was also reported by Kopp (1957) when harvested capsules were merely stored in a moist environment.

In his experiments Loftus Hills (1945) applied the equivalent of 50 mm of rain by one overhead irrigation to a poppy crop at different times. The treatments commenced at the green capsule stage nine days after petal fall and continued until dry harvest maturity. Morphine losses of 18% were recorded at each time of irrigation including the green capsule stages.

Bunting (1963) concluded that in dry seasons the moisture content of capsules was least when the morphine concentration in the capsules was maximal. However in unfavourable wet years the levels of morphine were only 30 to 79% of the former maximum by the time the capsules were ripe. In later glasshouse experiments Bunting applied simulated rainfall to poppy plants with a mist apparatus. With capsules about the stage of dry harvest

maturity morphine losses of 20% were recorded. If the waxy "bloom" on the surface of capsules was removed by hand rubbing in the green stage 2 - 4 weeks after full bloom 35% loss occurred. However if the "bloom" was not removed then no significant losses of morphine were observed (Bunting, Personal Communication).

1.6.3. The Effect of Capsule Fungi on Morphine Content

The decreases in the morphine content of poppy capsules which have been left in the field after the point of optimum dry maturity have also been attributed to the effect of fungal colonisation (Kopp 1957, Kleinschmidt and Mothes 1958, Miczulska 1967). Kopp expressed the view that fungi were also involved in the large seasonal variations - 0.17% to 0.90% over a five year period - in capsule morphine levels in Rumania.

In Poland, Miczulska (1967) concluded that there were large cultivar differences in susceptibility to fungal infection but that there was a close association between the extent of fungal infection and the decrease in capsule morphine. Where 50 percent of the surface area of capsules was covered by fungi then the morphine concentration of capsules was about halved compared with non-infected capsules. In Miczulska's experiments the fungi involved were Alternaria tenuis and Cladosporium herbarum.

The pathogens of P. somniferum and other members of the Papaveraceae have been recorded in a detailed review by Schmitt and Lipscomb (1975). In the European poppy growing areas Helminthosporium papaveris - the imperfect stage of Pleospora papaveracea - is widely recorded as being one of the most serious causes of yield decreases of poppies (Ballarin 1950). It is referred to as Parasitic Leaf Drying or Poppy Fire.

The perfect form of the disease can attack the growing plant at all times and all organs, roots, stem, leaf or capsule are all susceptible.

1.6.4. Metabolic Conversions of Morphine

The possibility that morphine may be metabolised within the plant is very relevant to any consideration of harvesting during the green stage for morphine extraction.

The steps in the synthesis of morphine from the precursor amino acid tyrosine have been delineated in precise details (Battersby and Harper 1958; Battersby et al 1962; Battersby and Francis 1964; Battersby, Foulkes and Binks 1965; Battersby, Martin and Brockmen Hanssen 1967). However the commonly held view (Saitseva 1959) that morphine was an end excretory product of plant metabolism that accumulated in the latex vessels during active growth and declined during senescence has changed. It was shown by feeding poppy capsules with labelled tyrosine and sampling at frequent intervals that there was a rapid turnover of some alkaloids and that morphine disappeared periodically from the system (Fairbairn, Paterson and Wassel 1964). This work confirmed and further elucidated the earlier similar experiments of Stermitz and Rapoport (1961). Later work by Fairbairn and El-Masry (1967) using radioactive morphine injected into the phloem region of the capsule pedicel further confirmed and explained the nature of the changes that involved morphine. The labelled morphine was quickly metabolized in the latex to form two non-alkaloidal polar substances which were rapidly translocated out of the latex. Subsequently these substances appeared in the pericarp and ovules. Part of the labelled morphine was transformed into amino acids and sugars.

Fairbairn and El-Masry (1968) later studied the important effect of these morphine breakdown products on seed development and germination but found that no morphine per se was present in the seed. They represented the general body of opinion that the occasional accounts of morphine in poppy seed (e.g. Preininger, Vrublovsky and Stasny 1965) were probably due

to contamination of the seed with fragments of capsule wall or surface smears of latex. However Sarkany, Michels-Nyomarkay and Verzar-Petri (1970) although agreeing that the seed lacked latex vessels did show the presence in seed of the alkaloids thebaine, narceine and narcotine. Also in contrast to the generally held view that the seeds of P. somniferum do not contain morphine as such, the recent work of Grove et al (1976) presented evidence that poppy seed did contain minute quantities of free morphine and codeine (1.7 ppm morphine and 0.5 ppm codeine). These authors felt that their technique had precluded the possibility of contamination from surface smears of latex. If the findings of Grove et al are in fact accurate then they may lead to a reassessment of the pathways of morphine metabolism in the poppy.

Further important work has focussed on the isolated latex in vitro. Such work has more clearly explained the nature of the synthesis and breakdown of morphine that occurs in the latex (Fairbairn and Wassel 1964; Meissner and Mothes 1964; Fairbairn, Djote and Paterson 1968). In addition it has helped define the precise latex particles (organelles) on which the metabolism of morphine occurs (Fairbairn et al 1968, Fairbairn and Djote 1970; Fairbairn, Hakim and El Kheir 1974) and has revealed valuable analogies and comparisons with the synthesis of rubber in the latex of Hevea brasiliensis (Dickenson and Fairbairn 1975). Other important contributions have been studies of the enzymes of general metabolism which are present in the latex of P. somniferum (Antoun and Roberts 1975).

1.7. The Nutrition of Papaver somniferum

1.7.1. Nitrogen

It is generally agreed that poppies have a high requirement for nitrogen and that nitrogen fertiliser application will give dry matter yield increases of stem and leaves, capsule and seed (Bagge 1953; Bunting 1956, Lecat 1956, Sherberstov 1956; Loof 1966). Rates of application giving responses ranged generally between 30 to 70 kg/ha of N but rates as high as 140 kg/ha N have been used with cultivars resistant to lodging (Dumont and Boulanger 1962, Loof 1966).

In some experiments higher yields have been obtained by dividing the total nitrogen between an initial pre-sowing application and a subsequent application after emergence. Dutch experiments have shown increases in seed yield of 10-20% when two thirds of the nitrogen was applied between one and three weeks before flowering (Van Hoon 1958, 1959, 1962). However Bunting (1956) obtained yield increases to later top-dressed nitrogen only in cooler wet years and Nehring, Rzymkowski and Schutte (1945) also found that the effect was small and dependant on weather conditions.

The explanation of the difference between these responses to nitrogen may well be the fact that the Dutch cultivars were selected for seed production and not morphine.

The oil content of seeds has been both decreased (Bunting 1956; Szwadiak and Michna 1959) and increased (Tucholka and Kuzminska 1959) by nitrogen application. Similarly the morphine concentration of capsules has shown variable responses to nitrogen. Schroder (1963), Koschke (1963), Kuzminska (1966) and Zuravlev and Sherberstov (1970) all obtained increases while Bunting (1956) and Lecat (1956) showed a minimal effect of N application. Similarly in earlier studies Annett (1920) concluded that neither nitrogen nor any other fertilisers affected the morphine content of opium.

The form of nitrogen application has had some effect on yield com-

ponents. Kuzminska (1966) obtained greater morphine and codeine concentration in capsules with nitrate N than with ammonium N while Tacholka and Kuzminska (1966) recorded higher yields of stem, leaf capsule and seed with calcium nitrate than ammonium sulphate. However this may also have been a response to calcium or pH as well as nitrate. In this experiment the nitrogen and oil content of seeds was increased similarly by both forms of N.

In a more recent glasshouse experiment with flowing solution culture Costes et al (1976) also obtained higher yields of capsule and seed with nitrate than ammonium nitrogen using cultivars selected for alkaloid production.

1.7.2. Phosphorus

A number of authors have shown yield increases of capsule and seed with phosphorus application (Sheberstov 1956, Dumont and Boulanger 1962; Minkov 1964; Zuravlev and Sherberstov 1970). Yield responses in the European experiments have usually been to levels of application of 30-40 kg/ha P. However in the experiments of Bunting (1946) in southern England no consistent responses to phosphorus were obtained but only in some experiments. Available soil P levels appeared to account for these differences. In European fertiliser experiments the method of application was almost exclusively broadcasting and uniform mixing. However Sheberstov (1956) emphasised that because of its small seed size and slow rate of growth that the poppy had a high early requirement for phosphorus. Sheberstov obtained early responses from a small amount (10 kg/ha) of superphosphate drilled in contact with the seed.

In the French experiment with flow cultures already quoted, Costes et al (1976) concluded that the yield effect of phosphorus was primarily on the number of capsules per plant with a small effect on weight per capsule.

1.7.3. The Effect of Combined Nitrogen and Phosphorus

In Russian glasshouse and field experiments Zuravlev and Sheberstov

(1970) compared the effect of P alone with N + P using four different forms of N. P alone increased capsule yield by an average of 21% compared with zero fertiliser while the N + P combination increased capsule yield by 33%. These authors concluded that the addition of N improved the efficiency of P and also enhanced morphine accumulation in the capsule especially when applied during rapid growth. There was no difference between the alternative forms of N used. Naumova and Sheberstov (1971) compared different elemental ratios of N and P in a glasshouse experiment and found that a ratio of 1 : 1 gave the highest yield of capsule and total alkaloids. Similarly Kinoshita et al (1960) found that the highest yield of morphine and seed was given by an N : P ratio of 1 : 1.

The increased absorption of banded phosphorus by plants when nitrogen is added to the band has been a significant area of study in soil plant relations for more than twenty five years. The phenomena has been observed with a wide range of plants. Maize (Zea mays) (Robertson 1954), oats (Avena sativa) (Olsen and Dreir 1956), wheat (Triticum aestivum) (Rennie and Soper 1958), sugar beet (Beta vulgaris) and potatoes (Solanum tuberosum) (Grunes et al 1958).

This "N P" effect has been the subject of three interesting and detailed reviews(Grunes 1959, Cope and Hunter 1967, Miller 1974) and Cope and Hunter (1967) also included harvested yield data which they felt were final expressions of earlier N P uptake effects.

One of the most important factors involved in the "N P" effect is the intimate mixing of N and P in a single band (Miller and Ohlrogge 1958). Duncan and Ohlrogge (1958) also investigated this aspect of intimate mixing and band volume and found that there was no effect of N on P uptake if the P was uniformly mixed through the soil. However subsequent work by Mamaril and Miller (1970) showed that at very high application rates of uniformly mixed N and P the enhanced uptake of P did occur. They concluded therefore that the concentration of P and not the volume of fertilised soil

per se was the crucial point.

The ammonium form of nitrogen has been shown to give the greatest effect on fertiliser P absorption (Leonce and Miller 1966) and the mechanism of this effect is thought to be most probably related to the physiological capacity of the root to absorb P. Miller et al (1970) showed that the pH at the soil-root interface of maize was an important controlling factor in P absorption. Ammonium sulphate lowered this pH giving a higher proportion of P in the more soluble $H_2PO_4^-$ form rather than HPO_4^{--}. Nitrate nitrogen had the reverse effect. Riley and Barber (1971) found similar effects at the soil-root interface working with soybean (Glycine max).

1.7.4. Potassium

The older literature recorded that P. somniferum required large amounts of potash at the end of the vegetative phase (Garola 1929) and Schropp (1938) commented that potash deficiency in the poppy was shown by darkening of the leaf, a delay in flowering and a general retardation of development. Dumont and Boulanger (1962) and Loof (1966) also decided that the poppy had high requirements compared with other crops. Nevertheless other workers have found little response or negative effects from potassium application. Sheberstov (1956) found negative effects of potassium on morphine content of capsules and Schroder (1963, 1966) recorded similar depressions in the yield of capsule seed and morphine. Bunting (1956) also could find no effect of potassium on the development or dry matter yield of any plant component. In addition there was no effect of potassium on either morphine content of capsule or the chemical composition of the seed.

In a German experiment the application of potassium chloride to a loess soil resulted in heavy infestation of the poppy crop with the fungus Helminthosporium papaveris. Potassium sulphate had no effect and lime applied with potassium chloride reduced the incidence considerably (Hatzner

1958).

Generally there are fewer published observations on potassium than on nitrogen or phosphorus.

1.7.5. Calcium Magnesium and Sodium

There are very few early reports on the effect of applied calcium on the yield of poppies. Bunting (1956) found that it had no effect on crop development or yield. The experiment of Tucholka and Kuzminska (1966) already noted (1.7.1) in which calcium nitrate outyielded ammonium sulphate could conceivably be interpreted as a response to calcium or sulphur rather than a differential nitrate response. However the literature does not record any responses to sulphur.

In a study of the mineral content of various components of the poppy Coic et al (1968) showed that the leaf, stem, flowers and seed had relatively high levels of calcium and magnesium. Consistent with these results Costes et al. (1976) also obtained growth responses from both calcium and magnesium in their flowing solution culture studies. Both of these elements had effects on dry matter production rather than morphine concentration. Costes et al (1976) also found that sodium increased both capsule dry weight and morphine concentration.

Although these results are interesting the generalised recommendation of the authors that sodium and calcium should be applied in fertiliser practise for poppies seems premature without field confirmation or consideration of soil type.

1.7.6. Micronutrients

Apart from one reference to molybdenum increasing capsule and seed yield (Sheberstov and Arsjuhina 1968) the most widespread micronutrient deficiency recorded for P. somniferum is that of boron.

In the European production areas boron deficiency of oil poppies has been noted frequently. In severe cases, growth ceases at an early stage with death of the growing point, contracted internodes and rolling of the

leaves. In less severe cases flowers and capsules are deformed and ovules and seed decay (Brandenburg 1942). Where boron deficiency is severe and plant death occurs early, the region of the growing point takes on a deep blue or violet colouration and this may extend to the mid-rib of leaves (Zogg, 1944, 1946). These descriptions of boron deficiency symptoms in European poppy growing areas are very similar to those recorded in Tasmania as suspected boron deficiency symptoms (Laughlin Unpublished Data).

The effects of boron deficiency in the poppy can often be alleviated by the application of borax at the rate of 10 to 20 kg/ha either as a soil application in spring or as a foliar spray (Kuzminska, 1970; Bergstrom, 1942; Zogg, 1946, 1954). However borax applied at rates higher than 20 to 30 kg/ha can depress the yield of capsules and seed (Kuzminska 1970).

As with a number of other crops, boron deficiency of oil poppies can often be induced on some soils by the application of lime (Majewsky et al 1969) but Zogg (1946) could find no clear association with soil pH.

Reports of the effect of boron on the morphine concentration of poppy capsules and other plant parts are conflicting. In Russia, Sheberstov and Arsjuhina (1968) increased the morphine content of capsules in a pot experiment with either boron or molybdenum applied at 1 mg/kg and in Polish experiments Michna and Szwadiak (1964) obtained similar increases in morphine concentration if boron was applied in factorial combination with high levels of N P K fertiliser. However when boron was applied alone there were no increases in morphine concentration of capsules. But in contrast to these results solution culture experiments carried out in Yugoslavia by Mokranjac and Birmancevic (1964) showed that although boron was essential for growth there was no specific effect of boron on morphine concentration of capsules. Similarly Voskerusa (1964) increased seed yield by the combination of boron and complete N P K treatment but in this Czeckoslovakian experiment there was no effect on morphine concentration of capsules.

The possible explanation of these variable results seems to hinge on the extent to which factorial combinations of boron and NPK treatments were used in the various experiments. On certain soils there appear to be interactions between boron and one or more of the major elements - possibly nitrogen - leading to higher morphine concentration of capsules.

1.7.7. Soil pH

In the Russian literature the opinion is held that the oil poppy grows best in soils of pH 6.9 to 7.0 (Shulgin 1969). Similarly Japanese workers (Kinoshita et al 1962) found in a pot experiment that the highest yield of whole plant, morphine and seed occurred at pH 7.0.

2. NUTRITIONAL STUDIES WITH BANDED NITROGEN AND PHOSPHORUS FERTILISERS

2.1. Introduction

All of the experiments which will be described in this thesis were carried out on basalt derived krasnozem soil (Gosse, Northcote 1971). When the introductory experiments on the nutritional responses of P. somniferum were undertaken in the early 1960's the method of broadcasting and uniform mixing of fertiliser through the top 100 - 150 mm of soil was used. These introductory experiments were modelled on common European practices and rates of fertiliser application, and responses to P were demonstrated for both capsule and seed yield. Nitrogen fertiliser had no effect on dry matter yield but generally it increased capsule morphine content by about 10% while no responses were obtained with K fertiliser for either dry matter or morphine content. Later experiments quickly established that banding gave much higher yields (50%) of capsule and seed than the broadcast method. They also established that when a small quantity (10 kg/haP) of phosphorus fertiliser was drilled in contact with the seed in conjunction with 20 kg/ha P banded below the seed then yields were increased 50% compared with 30 kg/ha P all drilled below the seed. There was some evidence that when the contact P was applied as lime superphosphate (50% ground limestone + 50% superphosphate) there were higher yields of capsule than when superphosphate alone was the form of contact P.

Subsequent experiments in which the basal fertilisers were band drilled further confirmed that response to P application was commonly obtained but there was no response to potassium. Various forms and times of application of nitrogen fertiliser between emergence and flowering gave no difference in dry matter yield of either capsule or seed compared with the same quantity of nitrogen applied at sowing time. All forms and times of application of N also appeared to have the same effect on capsule morphine content (i.e. about 10% increase).

Plate 1. A general view of Forthside Vegetable Research Station showing krasnozem soil and characteristically undulating land of the North West Region of Tasmania.

All of the yields in the above experiments were measured at dry harvest maturity (85 to 90% dry matter of capsules) and this evidence supported by field observations led to the following recommendations for poppies grown on krasnozem: fertilizer either pre-drilled or band placed directly below the seed to give 20 kg/ha N, 40 kg/ha P, 40 kg/ha K. Where pre-drilling was used then 10 kg/ha P drilled in contact with the seed was recommended (Frappell. Personal Communication; Allen and Frappell 1970).

This earlier work with poppies provided the background for these later studies of ways in which the composition and placement of banded fertiliser could be manipulated to further increase yield.

The seed of P. somniferum is small (about 2 million/kg) and the seedling is slow to emerge and establish. Therefore on a krasnozem with a high free ferric oxide content and high phosphorus fixation capacity (Craley and Loveday 1961) it was reasonable to assume that the placement position of banded fertiliser with respect to the seed may be important. In addition, factorial experiments using ^{32}P with onions (Allium cepa) on the Tasmanian krasnozem had shown that when nitrogen in the ammonium form was initially mixed and banded with fertiliser P there was very significantly increased uptake of banded P when measured 50 days after seeding. This enhanced uptake occurred when the fertiliser band was drilled close (15 mm) directly under the seed but did not occur when the band was drilled 50 mm below the seed. Furthermore enhanced uptake only occurred at the relatively high rates of 100 kg/ha N and 150 kg/ha P and the pattern of bulb yields in subsequent glasshouse and field experiments mirrored that of early P uptake (Laughlin unpublished data).

The pattern of banded P uptake in the experiment with onions appeared to be similar to the general concept of the "NP" effect as described by Grunes (1959) and Müller (1974). Moreover the pattern of harvest yield of onion bulbs appeared to mirror the uptake effects in the way described by Cope and Hunter (1967). It was therefore hypothesized

that P. somniferum may respond to banded NP fertiliser in a similar way to that of onions on the krasnozem both with respect to early uptake of P from the band and the final yield of capsule and seed at dry harvest maturity.

The bulk of the Tasmanian krasnozems on which poppies are grown have a pH in the range 5.6 to 6.0. Therefore because of the observations that poppies appear to have an optimum pH of 7.0 (Kinoshita et al 1962, Shulgin 1969) it was also hypothesized that the crop would respond to lime.

The various aspects of (i) early uptake of fertiliser (ii) depth of banding (iii) harvest yield effects of NP combinations and (iv) the effect of lime application were studied in a series of glasshouse and field experiments.

2.2. The Effect of N and Depth of Placement on the Uptake of Banded P

2.2.1. Materials and Methods

Krasnozem soil from the Forthside Vegetable Research Station was air dried and sieved to pass a 5 mm screen. Five kg quantities of soil taken from the top 150 mm depth were placed in 200 mm diameter plastic pots with 20 mm of gravel in the bottom to give free drainage. The pH of the soil was 5.9, available phosphorus 27 ppm and available potassium 155 m.e. per 10 kg of soil. Both elements were extracted with 0.5 M sodium bicarbonate at pH 8.5 (Colwell 1965). This method was used for all soil P and K contents quoted in this thesis.

Radioactive monocalcium phosphate was obtained from the Radiochemical Centre at Amersham England and had been labelled with ^{32}P at a strength of 0.1 millicuries per gram of monocalcium phosphate. Monocalcium phosphate was applied at the following levels: P1 = 50, P2 = 100 and P3 = 200 kg/ha P, and ammonium sulphate at: No = zero, N1 = 50, N2 = 100 and N3 = 200 kg/ha N.

Full factorial arrangements of the NP treatments were banded at two depths directly below the seed, either 40 mm (D1) or 75mm(D2). The width of the band was 20 mm and all rates of application were based on row spacings of 200 mm. All treatments were replicated five times and set out in a completely randomized design which was re-randomized periodically during the course of the experiment. Poppy seed of a Tasmanian selection was covered with 15 mm of soil and leached with 30 mm of water and subsequently kept at field capacity during the course of the experiment. Following emergence all treatments were thinned to seven plants per plot and the tops were harvested 50 days after sowing and oven dried.

2.2.2. Assessment of Radioactivity

The quantitative assessment of radioactivity of the dried poppy plants was carried out with a thin-window Geiger-Muller tube in conjunction with an Ekco automatic scaler (N530C). The harvested tops were oven dried at 75°C, weighed and ground to pass a 1 mm sieve. Two samples of 0.1 g were then taken from each treatment, placed in a 25 mm planchet and the level of radioactivity counted.

2.2.3. Results and Discussion

The mean number of counts/second/plant is an index of the relative uptake of applied fertiliser phosphorus and these results are set out in Table 1.

Table 1. The effect of NP composition and placement position on the uptake of banded phosphorus (counts/sec/plant)

	(a) Fertilizer banded 40 mm below seed (D1)				(b) Fertilizer banded 75 mm below the seed (D2)			
	P1	P2	P3	Mean	P1	P2	P3	Mean
N0	47.4	65.8	56.1	56.4	47.0	32.7	45.2	41.6
N1	50.1	58.1	76.5	61.6	27.4	27.1	46.0	33.5
N2	40.7	52.5	51.2	48.1	38.2	36.4	41.0	38.5
N3	23.2	56.4	36.0	38.5	18.7	25.1	43.5	29.1
Mean	40.3	58.2	55.0		32.8	30.3	43.9	

L.S.D. Within tables $P < 0.05 = 21.6$ Marginal means $P < 0.05 = 10.8$

" " $P < 0.01 = 28.6$ $P < 0.01 = 14.3$

Table 1 indicates that there was a marked effect of applied fertiliser P on uptake into the plant while nitrogen had a generally depressing effect which was more pronounced at the lower levels of P. There was no evidence of an N X P interaction but there was a marked effect of depth of banding (D) and a significant P X D interaction. Implicit in this interaction is the conclusion that uptake of banded P reached its maximum at P2 when banded 40mm below the seed. When banded 75mm below the seed maximum uptake did not occur until P3.

The oven dry weight of the plant material used in this experiment is given in Table 2 and this shows that, in general, dry matter yields mirrored the P uptake effects.

Table 2. The effect of NP composition and placement position on the mean dry weight per plant (mg)

(a) Fertilizer banded 40 mm below seed (D1)

	P1	P2	P3	Mean
N0	235	305	244	261
N1	211	227	286	241
N2	155	188	183	175
N3	91	202	126	140
Mean	173	230	210	

(b) Fertilizer banded 75 mm below seed (D2)

P1	P2	P3	Mean
221	158	191	190
125	118	185	143
126	142	151	140
78	107	158	114
137	131	171	

L.S.D. Within tables $P < 0.05 = 83$ Marginal means $P < 0.05 = 42$

" " $P < 0.01 = 109$ $P < 0.01 = 55$

Blanchar and Caldwell (1966) have shown that 'N P' uptake effects are often dependent on a leaching of the fertiliser band with at least 20 mm of water. Although a leaching treatment was applied in this experiment it may have been insufficient to avoid the retarding osmotic effects described

by Carter (1967).

2.3. The Effect of Banded NP Fertiliser on Dry Capsule Yield

2.3.1. Materials and Methods

The experiment was laid down at Wesley Vale in August 1969 on a krasnozem soil of pH 5.7, available phosphorus 95 p.p.m., and available potassium 125 m.e./10 kg of soil. Both elements were extracted with 0.5 M sodium bicarbonate. (See section 2.2.1.)

Ammonium sulphate was the form of nitrogen used and this was applied at the following levels: N0 = Zero, N1 = 28 and N2 = 56 kg/ha N. Superphosphate was the form of phosphorus and this was applied at P0 = Zero, P1 = 45 and P2 = 90 kg/ha. A full factorial arrangement of the above was predrilled 25 mm below the seed and superphosphate (CP) was drilled in contact with the seed on a split block basis to give CP0 = zero and CP1 = 34 kg/ha P. A full factorial arrangement of main plots was set out in a randomised block design with three replications.

The fertilisers were applied pre-drilled with a Massey Ferguson drill in rows 180 mm apart. Seed of a Tasmanian cultivar was then drilled in rows 180 mm apart but at right angles to the fertiliser bands. The plot size was 9.2 metres long by 2.3 metres wide and a quadrat of 3.1 x 1.5 metres was taken as the final harvest unit. After harvesting the dried capsules were crushed and the yield of capsule and seed recorded separately. Terminal and lateral capsules were bulked together.

A sub-sample of 100 grams of dried capsule was taken for the determination of morphine. This was done by extracting it from the ground capsule with calcium hydroxide solution. After reduction with iodic acid at pH 1.5 the morphine was complexed with nickel in a buffered ammonia solution at pH 8.0. The optical density was corrected for pseudo-morphine by using the ratio of absorbances at 670 mμ and 520 mμ and the morphine concentration was calculated with reference to a calibration curve of pure morphine concentration against absorption at 670 mμ (Pride and Stern, 1954).

This method was used for all experiments in this thesis. By multiplying the yield of dried capsule by its morphine percentage the yield of morphine was obtained.

2.3.2. Results

The yields of capsule seed and morphine are given in Tables 3, 4 and 6. It can be seen that the interactions of N X P are most marked and greatly modify any conclusion that can be drawn from the main effects of N and P. The N X P interaction was significant ($P< 0.01$) for capsule, seed and morphine yield as was the linear X linear component of this interaction.

Table 3. The effect of banded NP fertiliser and contact superphosphate on the yield of capsules (kg/ha).

(i) No contact "super"

	P0	P1	P2	Mean
N0	618	725	683	675
N1	618	739	781	712
N2	631	704	941	758
Mean	622	722	802	

(ii) "Super" in contact with seed

P0	P1	P2	Mean
791	818	646	750
695	818	840	784
747	812	898	818
744	816	794	

L.S.D. $P < 0.05$ within tables = 138

$P < 0.01$ " " = 192

For capsule yield, predrilled fertiliser (Table 3(i)) gave a significant ($P< 0.05$) response to N and a significant response to P ($P<0.01$) with a significant N X P interaction ($P< 0.01$). Neither the effect of contact fertiliser (Table 3(ii)) nor the interaction predrilled X contact was significant.

Table 4. The effect of banded NP fertiliser and contact superphosphate on the yield of seed (kg/ha).

	(i) No contact "super"				(ii) "Super" in contact with seed			
	P0	P1	P2	Mean	P0	P1	P2	Mean
N0	932	1184	1027	1047	1334	1328	954	1205
N1	962	1212	1406	1186	1097	1334	1485	1306
N2	919	1069	1457	1148	1198	1392	1556	1382
Mean	938	1155	1289		1211	1351	1332	

l.s.d. $P < 0.05$ within tables = 262

$P < 0.01$ " " = 363

For seed yield, predrilled fertiliser (Table 4(i)) gave a significant ($P < 0.01$) response to P and a significant N X P interaction ($P < 0.01$). The effect of contact-drilled fertiliser was not significant but the interaction between predrilled P fertiliser and additional contact drilled P was significant ($P < 0.05$).

Table 5. The effect of banded NP fertiliser and contact superphosphate on the morphine concentration of capsules (%).

	(i) No contact "Super"				(ii) "Super" in contact with seed			
	P0	P1	P2	Mean	P0	P1	P2	Mean
N0	1.11	0.95	0.94	1.00	1.04	0.97	1.03	1.01
N1	1.10	1.05	1.04	1.06	1.02	1.08	1.12	1.07
N2	1.12	1.06	1.11	1.09	1.09	1.06	1.14	1.09
Mean	1.11	1.02	1.03		1.04	1.04	1.09	

l.s.d. $P < 0.05$ within tables 0.09

$P < 0.01$ within tables 0.12

With predrilled fertiliser (Tables 5(i)) morphine concentration showed a significant response to N ($P < 0.01$). The interaction between predrilled P and contact-drilled P was also significant ($P < 0.01$).

Table 6. The effect of banded NP fertiliser and contact superphosphate on the morphine yield of capsules (kg/ha).

(i) No contact "super"					(ii) "Super" in contact with seed			
	P0	P1	P2	Mean	P0	P1	P2	Mean
N0	6.86	6.88	6.39	6.73	8.18	8.16	6.59	7.62
N1	6.74	7.72	8.16	7.51	7.13	8.84	9.41	8.41
N2	7.06	6.86	10.50	8.18	8.05	8.56	10.25	8.97
Mean	6.84	7.17	8.30		7.73	8.52	8.74	

l.s.d. $P < 0.05$ within tables 1.75

$P < 0.01$ " " 2.41

Table 6(i) shows that there was a significant effect of N and P on morphine yield ($P < 0.05$) and a significant N X P interaction ($P < 0.01$).

2.3.3. Discussion

The generalized pattern of response which gave rise to the N X P interaction in this experiment was due to lack of response to nitrogen at P0 and P1 and a markedly positive effect of nitrogen at P2. It could be suggested that the rate of root development at P0 and P1 was too slow to withstand the osmotic effect of nitrogen. However at P2 the rate of growth may have been just enough not only to withstand any detrimental effect of nitrogen but to benefit positively from nitrogen application.

The fact that the N X P interaction effect in terms of harvest yield of capsule, seed and morphine was marked on a soil ranking very high in available P(95 p.p.m.) appears to support the conclusions of Miller and Ohlrogge (1958) that the effect of nitrogen on the uptake of band drilled phosphorus is independent of soil phosphorus level.

In tables 4 and 5 it can be seen that the interaction between predrilled P and contact-drilled P was significant ($P < 0.05$) in the case of seed weight and percentage morphine. However in no case was the main effect of contact P significant although the mean yields were often

numerically higher. To a large extent this is attributable to the split block design (Cochran and Cox 1966) used in this experiment because the design was selected to measure the interactions with far more precision than main effect. Because of this, the number of degrees of freedom for the error term applied to contact fertilizer were very low and made it virtually impossible to show significance to the main effect of contact P. The interaction between contact P and P band drilled below the seed underlined the high phosphorus requirement of the oil poppy on the krasnozem. Even though the predrilled fertilizer was only 25 mm below the seed it could be displaced laterally up to 90 mm away, i.e. mid-way between two rows of seed spaced at 180 mm. In the short but possibly critical period before the roots of the poppy tap the predrilled band the contact P may play a vital role. Thus the use of contact P might be most effective in the situation of predrilling where the bands of fertilizer occur in all random positions from directly below the seed to a lateral displacement of 90 mm away. Where specialized placement drills are used to maintain a consistent relationship between seed and fertilizer - e.g. fertiliser directly below the seed - then contact P may not have such a large effect.

The fact that the linear X linear component of the N X P interaction for both capsule and seed yield was so highly significant suggested that the additional yield responses might be expected from high rates of application. However the banding of higher rates of nitrogen near the seed could also increase the possibility of osmotic injury (Carter 1967). This suggested that the higher rates should be placed at a greater distance from the seed in subsequent experiments.

2.4. The Effect of NP Composition and Depth of Banding on the Yield of Mature Dry Capsules

2.4.1. Materials and Methods

The experiment was laid down at Forthside Vegetable Research Farm on a krasnozem soil of pH 6.1 with an available phosphorus status of

40 p.p.m. and an available potassium status of 99 m.e./10 kg of soil (See section 2.2.1.).

Nitrogen was applied as ammonium nitrate at the following levels: N0 = zero, N1 = 50 and N2 = 100 kg/ha N. Phosphorus was applied as concentrated superphosphate containing 20% P to give P1 = 50, P2 = 100 and P3 = 150 kg/ha P. A full factorial arrangement of the above treatments was applied at two different depths directly below the seed: D1 = 15 and D2 = 65 mm.

A supplementary factorial experiment to test the effect of contact lime at rates of L0 = zero and L1 = 500 kg/ha of ground limestone and contact superphosphate at CP0 = zero and CP1 = 500 kg/ha of superphosphate was randomised throughout the main experiment. Each of the contact treatments of lime and superphosphate had the treatment N1 P2 drilled at depth D2 below the seed.

In addition to the main factorial experiment above, there were additional plots to test:-

(i) The effect of N1 P2 using alternative forms of N as ammonium sulphate and P as ordinary superphosphate (10%P) drilled below the seed at depth D2.

(ii) The effect of N2 P3 drilled at an intermediate depth, 40 mm below the seed.

The full factorial arrangement of N and P banded below the seed together with the contact lime and superphosphate treatments were set out in a randomised block design with three replications. The experiment was established on 3rd September, 1970, with the fertilisers and seed being applied with an N.I.A.E. placement drill incorporating a seeding device which operated simultaneously with the fertiliser. Poppy seed of a Tasmanian selection was drilled in 400 mm rows and the plot size was 11 m long and 1.6 m wide. The two middle rows x 8 m long were taken as the final harvest plot. After hand harvest, the dried capsules were threshed

and the yield of capsule and seed recorded separately.

2.4.2. Results

The Effect of Position of the Fertiliser Band

The comparison of the yields obtained when fertiliser was banded very closely (15 mm) below the seed and 65 mm below is set out in Table 7 while a third intermediate distance of 40 mm below the seed is also compared in Table 8.

Table 7. The effect of depth of fertiliser band placement on capsule, seed and morphine yields (kg/ha).

Depth below seed (mm)	Yield (kg/ha)			Morphine Content (%)	Capsule/ Head %
	Seed	Capsule	Morphine		
15 (D1)	1258	2564	7.7	0.61	32.9
65 (D2)	1201	2488	7.1	0.59	32.5
l.s.d.	N.S.	N.S.	N.S.	N.S.	N.S.

No significant differences were obtained for any production characteristics at these two depths. These results are the means of all appropriate treatment included in the factorial arrangements. In addition, one extra treatment was included to compare another depth, 40 mm below the seed, at one NP combination and the results obtained for this comparison are given in Table 8.

Table 8. The effect of depth of fertiliser band below seed using N2 P3 mixture on capsule and morphine yields (kg/ha).

Depth below seed (mm)	Yield (kg/ha)			Morphine Content (%)	Capsule/ Head %
	Seed	Capsule	Morphine		
15	3250	1580	9.7	0.62	32.7
40	2340	1360	7.8	0.57	33.7
65	2820	1410	8.8	0.56	33.0
l.s.d.	N.S.	N.S.	N.S.	N.S.	N.S.

When banded 15 mm below the seed the high concentration of fertiliser may have inhibited growth because of high osmotic pressure. Also at 65 mm it is possible that leaching of nitrogen could have occurred before being reached by the plant roots. The response to the fertilizer banded in the intermediate position 40 mm below the seed suggested that neither injury nor positional unavailability was of significance in this experiment.

The Effect of N and P Fertiliser Banded Below the Seed

Because there were no differences in yield between D1 and D2 the yields of the various N P factorial combinations are set out below as the mean of these two depths. The yields of seed, capsule and morphine are set out in Tables 9, 10 and 12 and the total capsule morphine concentration in Table 11. Table 13 records the percentage contribution of the empty capsule to the intact head containing seed.

Table 9. The effect of N and P banded fertiliser on the yield of seed (kg /ha)

	P1	P2	P3	Mean
N0	2310	2760	2585	2550
N1	2495	2425	2505	2475
N2	2190	2425	3035	2550
Mean	2330	2535	2710	

L.S.D. $P < 0.05$ within tables = 436

marginal means = 252

$P < 0.01$ within tables = 584

marginal means = 337

For seed yield (Table 9) there was a significant ($P < 0.05$) response to P and a significant ($P < 0.05$) N x P interaction.

Table 10. The effect of N and P banded fertiliser on the yield of capsules (kg/ha)

	P1	P2	P3	Mean
N0	1095	1260	1170	1175
N1	1230	1180	1235	1215
N2	1165	1235	1495	1300
Mean	1165	1225	1300	3690

L.S.D. $P < 0.05$ Within tables = 203

Marginal means = 117

$P < 0.01$ Within tables = 272

Marginal means = 157

Although the mean responses to both N and P were significant the linear component of these responses were both significant ($P < 0.05$).

Table 11. The effect of N and P banded fertiliser on capsule morphine concentrations (%)

	P1	P2	P3	Mean
N0	.575	.612	.604	.598
N1	.604	.579	.561	.581
N2	.622	.597	.622	.614
Mean	.601	.597	.596	

There were no significant effects of either N or P fertiliser application on morphine percentage.

Table 12. The effect of N and P banded fertiliser on the yield of capsule morphine (kg/ha)

	P1	P2	P3	Mean
N0	6.3	7.8	7.1	7.1
N1	7.6	6.9	7.0	7.1
N2	7.2	7.4	9.3	8.0
Mean	7.0	7.4	7.8	

There were no significant mean effects due to either N or P fertilizer application but the N quadratic x P linear component of the N x P interaction very closely approached significance.

Table 13. The effect of N and P banded fertiliser on the capsule to head* percentage (%)

	P1	P2	P3	Mean
N0	32.15	31.20	31.35	31.57
N1	33.20	32.50	33.00	32.90
N2	34.70	33.65	33.00	33.78
Mean	33.35	32.45	32.45	

* The head is the intact air-dried capsule containing seed.

L.S.D. $P < 0.05$ within tables = 0.82

marginal means = 0.48

$P < 0.01$ within tables = 1.10

marginal means = 0.64

In terms of capsule to head percentage there were significant effects ($P < 0.01$) attributable to both N and P fertilizers. In most years the capsule contributes 40% of total head weight.

The Effect of Contact Fertiliser

A supplementary factorial design incorporating the effect of contact lime and superphosphate was randomised within the main experiment and the results are recorded in Table 14.

Table 14. The effect of ground limestone and superphosphate placed in contact with the seed on dry matter and morphine yield (kg/ha).

Contact Treatment	Capsule kg/ha	Seed kg/ha	Morphine Yield kg/ha	Morphine	Capsule/ Head %
L0 CP0	1180	2420	6.7	0.56	32.7
L0 CP1	1250	2490	6.8	0.55	33.3
L1 CP0	1120	2240	6.3	0.56	33.3
L1 CP1	1350	2690	8.4	0.62	33.3
L.S.D.	N.S.	N.S.	N.S.	N.S.	N.S.

The treatment N1 P2 was band-drilled at depth D2 (= 65 mm) directly below the seed of all treatments in the above 2 x 2 factorial of contact lime and superphosphate (10% P). There were no significant harvest yield effects from contact fertilizer on any yield characteristic.

The Effect of Different Forms of Fertiliser

Table 15. Yield effects from different forms of nitrogen and phosphorus (kg/ha)

Treatment	Depth below seed (mm)	Nitrogen	Phosphorus	Capsule	Seed	Morphine %	Morphine Yield	Capsule Head %
N1 P2	65	Ammonium Nitrate	Concentrated Super (20%P)	1180	2420	0.563	6.643	32.7
N1 P2	65	Ammonium Sulphate	Ordinary Super (10%P)	1150	2320	0.570	6.555	33.0
L.S.D.				N.S.	N.S.	N.S.	N.S.	N.S.

For the treatment N1 P2 D2 there were no significant differences between the contrasting forms of nitrogen and phosphorus used.

2.4.3. Discussion

In Table 9 it can be seen that there was a significant ($P < 0.05$) N x P interaction in terms of seed weight. Also in Table 12 the N quadratic X P linear component of the N x P interaction closely approached significance ($P < 0.05$) for yield of morphine. With respect to capsule yield the N x P interaction effect was not significant although the pattern of yield responses to N and P followed the generalized pattern which gave rise to the N x P effect. This yield pattern is best illustrated by the seed yield of Table 9 in which where is a depressing effect of nitrogen at P1 and P2 but a marked positive effect at P3.

In this experiment ammonium nitrate was chosen as the form of N and concentrated superphosphate as the form of P so that the level of applied sulphur would be minimal. The reason for this was because it has been shown by Menary and Hughes (1967) on a similar krasnozem soil that S x P interactions may occur and could possibly confound the N x P interactions. However subsequent experiments on the Tasmanian krasnozem showed in the case of onions (Allium cepa L) that although marked N x P harvest yield effects occurred, S x P yield effects did not. (Laughlin. Unpublished data).

However it has also been shown (Riley and Barber, 1969 and 1971; Millier et al, 1970) that the application of N as NH_4^+ ion resulted in a decrease in the pH of the rhizocylinder (i.e. roots + strongly adhering soil) whilst fertilization with N as NO_3^- increased the rhizocylinder pH. The direction and amount of pH change is attributable to the relative rate of cation or anion absorption by the root. When N was taken up as the NH_4^+ ion, cation uptake exceeded anion uptake and H^+ ions were released to balance the charge. If N was absorbed as NO_3^- anion uptake was accentuated and OH^- or HCO_3^- ions were released to balance the excess anion absorption.

Riley and Barber (1969) found that the form of N absorbed could cause a difference in pH of the rhizosphere of as much as 2 pH units.

The significance of this localized change in pH of the rhizocylinder, or the soil-root interface, is that phosphorus is commonly absorbed from this small cylinder of soil surrounding the roots because P diffuses at a very slow rate through the soil (Barber et al 1962; Lewis and Quirk, 1967). As soil pH markedly influences P solubility, the form of N which is used will alter fertilizer P availability and uptake.

Riley and Barber (1971) found greater uptake of banded fertilizer P in roots and tops of soybean when NH_4^+ was mixed with P than when NO_3^- was used. A similar result was found by Blair et al (1971) with maize and they found a higher ratio of $H_2PO_4^-/HPO_4^=$ ions, when ammonium -N was combined with P than when P was used alone or combined with nitrate -N. The more soluble $H_2PO_4^-$ ion leads to greater uptake.

The significance of the references to the differential effect of ammonium and nitrate-N is that by using ammonium nitrate as the form of N in the field experiment with oil poppies, it is quite possible that the N x P interaction effect may have been significantly lessened. This is for the reasons set out above that ammonium N can have a far greater effect on fertilizer P uptake than nitrate N. However the data in Table 15 suggest that in this particular experiment at least there was no marked difference between the two forms of N.

One of the most striking features of this experiment was the very low morphine concentration in capsules generally (Table 11). There was no effect of nitrogen fertiliser on morphine levels and the overall mean of 0.59% was little more than half that of previous seasons (e.g. Table 5). The experimental crop experienced wet humid conditions prior to and about the time of dry maturity, with some delay in harvest together with severe fungal infection of the heads. The implications of both of these factors and the investigations undertaken to assess their possible importance will

be discussed in Sections 3. and 6.

2.5. The Effect of Liming on Plant Yield and Nutrient Content

2.5.1. Materials and Methods

This glasshouse pot experiment was carried out at the New Town Research Laboratories of the Tasmanian Department of Agriculture and used the 0 - 150 mm layer of a krasnozem from Forthside Vegetable Research Station. The initial pH was 5.2 and the initial available soil phosphorus was 36 ppm while the potassium status was 32 m.e./10 kg of soil (See section 2.2.1.).

The air-dried soil was passed through a 5 mm sieve. Calcium hydroxide was applied broadcast to the soil and uniformly worked throughout the whole soil volume in quantities equivalent to zero, 2.5, 5, 10, 15, 20, 25 and 50 tonnes/ha. 5 kg samples of these mixtures were placed in 200 mm plastic pots with free draining crocks in the bottom.

All limed treatments had a band of superphosphate and ammonium sulphate placed directly below the seed to give rates of 60 kg/ha P and 30 kg/ha N based on 180 mm row spacings.

In addition to these treatments there was a separate set of treatments in which $Ca(OH)_2$ was applied only in contact with the seed at the following rates of application:- 100, 200, 400, 600, 800 and 1000 kg/ha. These treatments also had the same basal N P fertiliser drilled 25 mm below the seed as with all other treatments. The rates of application of contact $Ca(OH)_2$ were also based on 180 mm rows. The full experiment was set out in randomised blocks with six replications.

Fifteen seeds per pot of a Tasmanian cultivar were sown and covered with 10 mm of soil and all treatments were initially leached with 25 mm of water and subsequently kept at field capacity during the course of the experiment. A count was taken of germination and final survival and the plants thinned to two per plot.

At dry harvest maturity the number and weight of capsules was recorded and also the weight of seed and stem plus leaves. At the completion of the experiment the final soil pH and the available soil phosphorus and potassium were determined. Both of these determinations were done on a soil core taken vertically through the depth of the pot and 50 mm from the central fertiliser band.

At dry harvest a chemical analysis of the stem and leaves was also carried out. Phosphorus was determined by the molydovanodo-phosphoric acid method (Quinlan 1955), molybdenum by the colorimetric dithiol method (Bingley 1963) and boron by the curcumin method (Dible, Truog and Berger 1954). Potassium, sodium, magnesium calcium, manganese, zinc and copper were determined by atomic absorption spectrophotometry.

2.5.2. Results

The main yield data of capsule and seed are set out in Table 16 with that of stem plus leaves in Table 19 and some of these data required logarithmic transformation. In Table 17 the soil P and K status and the bulk soil pH at the completion of the experiment are shown. Because of the drastic effect on survival the 50 tonnes/ha of $Ca(OH)_2$ broadcast and the 800 and 1000 kg/ha of $Ca(OH)_2$ banded treatments were excluded from the statistical analysis of yield data in Tables 16 and 19.

Table 16. The effect of broadcast and contact Ca(OH)2 on plant survival and yield of dry capsules (g/pot*)

Ca(OH)2	Survival No. of plants/ Pot	No. of Capsules/ Pot	Capsule Yield/ Pot	Trans-* formed Capsule Yield/ Pot (logs)	Seed Yield/ Pot	Trans-* formed Seed Yield/ Pot (logs)	Capsule** Morphine Content %
Broadcast							
Zero t/ha	11.20	1.80	0.48	-0.80	0.83	-0.26	1.6
2.5	12.00	2.00	1.37	0.30	2.08	0.72	1.4
5	12.80	2.00	1.49	0.38	2.30	0.83	1.4
10	13.70	2.00	1.80	0.58	2.99	1.08	1.3
15	13.80	2.00	3.09	1.12	3.89	1.33	1.3
20	14.30	2.17	3.28	1.16	4.09	1.39	1.4
25	12.20	3.00	4.65	1.53	5.10	1.61	1.3
50	4.50						1.4
Contact							
100 kg/ha	10.20	2.00	0.84	-0.19	1.26	0.19	1.5
200	11.20	2.00	0.82	-0.21	1.28	0.20	1.3
400	7.80	2.00	1.00	-0.02	1.52	0.41	1.3
600	8.50	2.00	1.14	0.13	1.53	0.42	1.4
800	3.20						1.3
1000	3.30						1.4
l.s.d.							
P<0.05	2.51	0.20		0.24		0.28	
P<0.01	3.34	0.27		0.32		0.38	

* The transformations used in Table 16 above are logarithmic transformations to base e and hence yields less than 1g are negative values.

**Morphine analyses were not based on fully replicated data.

The first noticeable effect of $Ca(OH)_2$ application was on emergence. When uniformly mixed throughout the soil there was no detrimental effect up to and including the 25 tonnes/ha treatment. The 50 tonnes/ha broadcast treatment markedly reduced survival and those plants which did survive were on the very edge of the pots. They were considered to be atypical and were therefore not included in the yield analysis. $Ca(OH)_2$ banded with the seed had a significant effect on survival at the 400 kg/ha rate and survival was markedly decreased ($P < 0.01$) at 800 kg/ha. For the same reason as the 50 tonnes/ha. treatment above, both the 800 and 1000 kg/ha contact treatments were excluded from the yield analysis.

In Table 17 it can be seen that there was a progressive change in soil pH with the application of $Ca(OH)_2$ so that virtual neutrality (pH6.96) was achieved with the application of 10 tonnes/ha from an initial pH of 5.3 . After the application of 15 tonnes/ha the rate of pH increase slackened markedly and the krasnozem soil in this experiment appeared to buffer over the range pH 7.9 to 8.2 .

With rates of $Ca(OH)_2$ application greater than 10 tonnes/ha there was significant ($P < 0.01$) increase in available soil P and this increase continued up to the 50 tonnes/ha application. The effect on available soil K was opposite to that on soil P so that there was a tendency for soil K to decrease as pH increased.

Table 17. The effect of Ca(OH)2 on soil pH and available phosphorus and potassium five months after application

Ca(OH)2	Soil pH	Available soil phosphorus (ppm)	Available soil potassium (m.e./10 kg)
Zero + N P	5.3	38	29.84
2.5 t/ha broadcast	5.9	39	17.00
5 "	6.3	36	17.34
10 "	7.0	40	15.50
15 "	7.9	53	13.00
20 "	8.0	56	13.50
25 "	8.1	61	12.84
50 "	8.2	76	15.34
l.s.d. $P < 0.05$	0.10	5	2.53
$P < 0.01$	0.14	7	3.38

The mineral contents of stem and leaves harvested at dry maturity are set out in Table 18 and these were based on four replications. The contents of most elements followed predictable patterns except phosphorus, copper and manganese.

Table 18. The effect of Ca(OH)2 application on the mineral content of stem and leaves

Ca(OH)2 (t/ha)	P (%)	K (%)	Ca (%)	Mg (%)	Na (%)	Mo (ppm)	B (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)
0	0.04	1.1	NA	NA	NA	1.5	NA	12.3	NA	NA
2.5	0.09	2.0	1.8	0.30	0.90	1.0	43.5	7.3	159.3	41.8
5	0.07	1.8	1.4	0.26	0.70	1.2	30.5	7.2	75.3	7.5
10	0.14	1.3	1.9	0.36	0.84	3.4	31.5	9.8	58.0	22.5
15	0.08	1.0	1.7	0.39	0.80	2.7	28.3	8.5	53.0	42.8
20	0.07	1.1	1.8	0.44	1.66	4.0	30.5	13.5	43.8	62.5
25	0.05	1.1	2.0	0.44	1.60	5.2	34.3	18.4	62.0	80.5
50	0.02	1.1	1.4	0.44	0.79	6.5	29.0	23.1	40.5	85.0
5%	NS	0.5	NS	0.07	0.71	1.5	6.9	NS	22.2	23.4
l.s.d 1%		0.6		0.09	0.97	2.0	9.4		29.1	36.2

NA = Not Available

The yields of stem and leaves harvested at dry maturity are recorded in Table 19 and these are the means of six replications. The pattern of yield response of the stem plus leaf component to Ca (OH)2 application was very similar to the effect on capsule and seed. Maximum yield occurred at 25 t/ha broadcast.

Table 19. The effect of broadcast and contact Ca(OH)2 on mature dry yield of stem and leaves (g/pot*)

Ca(OH)2	Yield of stem plus leaves	
	(g/pot)	Transformed* (logs)
Broadcast		
Zero t/ha	1.94	0.61
2.5	6.00	1.79
5	6.83	1.88
10	8.42	2.12
15	11.63	2.44
20	12.73	2.54
25	16.36	2.79
Contact		
100 kg/ha	3.32	1.19
200	3.30	1.19
400	4.56	1.49
600	4.38	1.47
l.s.d. $P \leq 0.05$		0.201
$P < 0.01$		0.268

* The yield transformation used in Table 19 is a logarithmic transformation to base e.

2.5.3. Discussion

Yields of capsule seed and stem plus leaves increased progressively up to the 25 t/ha broadcast treatment with a significant ($P < 0.01$) difference between the 25 and 20 t/ha level for capsule and stem plus leaf yields (Tables 16, 19). Yield of capsule was also increased by $Ca(OH)_2$ bandod with the seed so that yield of the 600 kg/ha treatment was significantly ($P < 0.05$) greater than the 200 kg/ha treatment. However $Ca(OH)_2$ far more effectively increased capsule yield when broadcast and uniformly worked through the soil volume of the pot than when banded with the seed.

Part of the capsule yield effect of the 25 t/ha $Ca(OH)_2$ broadcast was attributable to the greater mean number of capsules per pot. The number of capsules given by this treatment was significantly ($P < 0.01$) greater than any other treatment (Table 16). There was insufficient capsule material available to perform a completely replicated series for morphine analysis so that statistical analysis was not carried out on these figures. However the mean morphine contents in Table 16 suggest that bulk soil pH even up to 8.2 (Table 17) will not markedly affect morphine concentration in the capsules. Therefore it follows that the yield of morphine in this experiment would probably have increased proportional to capsule yield increase as pH rose.

Although the maximum yield of capsule and seed was achieved in this experiment at a bulk soil pH of 8.1 it is very likely that the localised region around the band was quite different to this. The soil was sampled 50 mm from the edge of the band in this experiment and Isensee and Walsh (1971) found that soil sampled close to a fertiliser band was quite different to bulk soil pH. In the case of treatments approximately comparable to the N P band in this experiment these workers found that pH readings were one unit lower in the region 10 - 40 mm from the centre of the band than those in the bulk soil.

The N P fertiliser band in this experiment was placed 25 mm directly below the seed. Therefore it seems reasonable to suggest that the treatments involving $Ca(OH)_2$ in contact with the seed may have given lower yields because of unfavourable localised pH effects rather than a direct effect on seed per se. It is a general observation that there is a dense proliferation of roots around an N P fertiliser band (Duncan and Ohlrogge 1958, Miller and Vij 1962) and thus the region is probably specially important in the uptake of many nutrients. This point should be considered when assessing the general plant nutrient status in Table 18. Despite the relatively large increase in available soil P(Table 17) the plant P levels did not increase. However plant K levels did decline in concert with decreases in available soil K (Table 17).

The plant molybdenum levels in Table 18 show a consistent increase with increasing rates of $Ca(OH)_2$. Also the general pattern of high magnesium and sodium at the 25 t/ha level of application appears to support the contention of Costes et al (1976) that the poppy will respond to both of these elements. Boron levels fell with increasing $Ca(OH)_2$ but even at the highest application rate, tissue levels were within the range generally considered adequate (Jones 1972). The high tissue levels of copper for the 25 t/ha $Ca(OH)_2$ treatment are quite inconsistent with the generally accepted effect of sharply decreasing available soil copper levels as soil pH increases from pH 5 to 8 (Lindsay 1972).

2.6. Conclusions

The experiment on uptake of banded P (Table 1) failed to show any positive effects from N application. In fact nitrogen depressed uptake of banded P. However the two field experiments at Wesley Vale (Tables 3, 4, 6) and Forthside (Table 9) both demonstrated N X P interaction effects in terms of dry harvest yield which conformed to a consistent pattern: that is, no response to N at zero and relatively low levels of P and a positive effect at relatively high levels of P. This

pattern of harvest yield was similar to the harvest yield effects described by Cope and Hunter (1967) and to the uptake effect of N on P which has been shown by a number of authors (Grunes et al 1958, Werkhoven and Miller 1960, Mamaril and Miller 1970) - similar in the sense that relatively high levels of both N and P were required for both increased uptake and increased harvest yield to occur.

The effect of depth of banding below the seed showed that maximum uptake occurred at a lower application rate (100 kg/ha) from the shallower band (40 mm) compared with the band placed 75 mm below the seed (Table 1). In contrast to this there was no difference in terms of mature dry harvest yield of capsule and seed between NP fertilizer banded 15 mm and 65 mm directly below the seed (Table 7). One practical implication of the data in Table 7 is that given that poppy seed is commonly sown at a relatively shallow depth of approximately 15 mm below the soil surface it would be better to drill the fertilizer 65 mm below the seed. In the case of dry conditions and particularly with non-irrigated crops the deeper placement would be in moister soil with a greater probability of being available.

The effect of increasing soil pH by calcium hydroxide application had a marked impact on the yields of dry capsules, seed and stem plus leaves at all levels of application. However it is difficult to be specific on the major reason or reasons for the significant increase in yield between the 20 and 25 t/ha rate of $Ca(OH)_2$. The data in Table 18 suggest that availability of magnesium, sodium, molybdenum or copper may be involved.

3. THE EFFECT OF LEACHING ON THE MORPHINE CONTENT OF POPPY CAPSULES

3.1. Introduction

The physical leaching of morphine from the capsules of the poppy has been suggested as a cause of loss in wet weather (Loftus Hills 1945, Bunting 1963). In the nutritional experiment carried out in the 1970/71 season and described in section 2.4. of this thesis, wet and overcast conditions were encountered around the time the plants were approaching dry maturity. Harvest was delayed for a number of weeks and capsule morphine concentrations were little more than half the previous season or the averages in subsequent seasons.

Two experiments were carried out at the New Town Research Laboratories using simulated leaching techniques to assess the possible loss of morphine from this cause.

Experiment 3.2. used ground capsule material while experiment 3.3. used intact capsules.

3.2. Simulated Leaching of Ground Capsules

3.2.1. Materials and Methods

Samples of oven-dry ground capsule material weighing 4 g were mixed with deionised water to give the following combinations:-

(i) 50% capsule material + 50% water

(ii) 20% capsule material + 80% water

(iii) The 20% capsule material + 80% water mix was also subjected to a simulated leaching with the equivalent of 5 cm of water which was left in contact for two hours and then centrifuged at 7000 r.p.m. for twenty minutes.

(iv) The 20% capsule material + 80% water treatment was also subjected to two cycles of oven drying at 80°C until 80% dry matter had been achieved. This was to simulate the alternate drying and wetting which

may occur in the field when rain falls just prior to harvest.

(v) A control of air dried capsule.

All treatments (i) to (iv) were autoclaved at 118°C for 20 minutes and were held for ten days prior to analysis. There were three replications of each treatment set out in a completely randomised design.

After ten days the ground capsule material from all treatments was analysed for morphine (Pride and Stern 1954). In addition the leachates from the four replications of treatment (iii) were also analysed for morphine.

3.2.2. Results

The mean morphine contents of the capsule material from treatments (i) to (v) are set out in Table 20.

Table 20. Mean morphine content of ground capsule subjected to simulated leaching and related treatments (%)

No.	Treatment		% Morphine (after ten days)
(i)	50% Capsule + 50% water		0.497
(ii)	20% Capsule + 80% water		0.533
(iii)	20% Capsule + 80% water + leaching		0.217
(iv)	20% Capsule + 80% water + two drying cycles		0.563
(v)	Air dry capsule		0.560
	($P < 0.05$)	=	0.068
	($P < 0.01$)	=	0.095

The mean morphine content of the leachate from treatment (iii) was 0.42% but was not included in the statistical analysis.

The simulated leaching treatment (iii) more than halved the morphine content of the air dried capsule material (v) and this loss of

morphine was recovered in the leachate in the same chemical form as in the capsule. The difference between the morphine contents of the leached treatment (iii) and treatment (v) was highly significant ($P < 0.01$).

3.2.3. Discussion

Although the ground capsule material used in this experiment was very different to the intact capsule in the field the point was made that morphine could be washed out of the capsule material and was recovered in the leachate.

When a poppy crop is at or near dry harvest maturity the capsules very readily pick up and lose moisture. Bunting (1963) found that after overnight rain the ripe capsules had a moisture content of 45% but rapidly lost moisture to return to their previous 15% moisture next morning. In this present experiment treatment (iv) was included to assess whether a simulated drying cycle might be associated with a loss of morphine. The results of Table 19 did not show any evidence to support this possibility.

Kopp (1957) found that when harvested capsules were stored in a moist atmosphere that a significant reduction in morphine occurred. This observations implied that in the field situation if harvest was delayed by a continuation of humid weather - not necessarily rain - then capsule morphine may decrease. Possibly this might happen by some chemical conversion of morphine within the capsule wall perhaps involving hydrolysis. Treatment (i) (Table 20) did show a trend towards lower morphine after ten days in this experiment and in a related experiment 6.2. (Table 41) involving moistened capsule material there were significant decreases in capsule morphine after 24 days.

3.3. Simulated Leaching of Intact Capsules

3.3.1. Materials and Methods

A glasshouse experiment was conducted in which poppies were grown in 200 mm plastic containers filled with 5 kg of air-dry krasnozem soil

from Forthside Vegetable Research Farm. A Tasmanian cultivar was used with a fertiliser band of 40 kg/ha P and 40 kg/ha N placed 25 mm directly below the seed. The soil analysis was pH 5.8, available soil P. 40 p.p.m. and available K, 80 m.e./10 kg soil (Colwell 1965, see 2.2.1.). The soil was maintained at field capacity during the course of the experiment and the plants were thinned to four per pot at emergence.

Capsules were harvested at two weeks (T1), four weeks (T2) and six weeks (T3) after petal fall. The experiment was set up as a completely randomised factorial design with four replications and was re-randomised periodically during the course of the experiment. At each time of harvest the capsules were immersed in glass containers with 100 cc of distilled water for the following times:- L0 = Zero, L1 = 6.7 minutes, L2 = 44.8 minutes and L3 = 300 minutes. These times were chosen to give equal logarithmic increments.

The base of each capsule was sealed with paraffin wax to prevent loss of alkaloids from the severed ends and after immersion the capsules were chemically analysed for morphine. The immersion water was also analysed for morphine, both analyses following the method of Pride and Stern (1954) (See 2.3.1.).

3.3.2. Results

Table 21. The morphine content of leached capsules harvested periodically from petal fall to dry maturity (% of air dry capsule).

Length of Immersion (minutes)	Time of Harvest (weeks after full bloom)				Immersion Means l.s.d. P < 0.05
	2	4	6	Mean	
Zero	0.76	1.24	1.21	1.07	N.S.
6.7	0.59	1.11	1.16	0.95	
44.8	0.59	1.15	1.11	0.95	
300	0.74	1.02	0.98	0.91	
Mean	0.67	1.13	1.12		

l.s.d. Time P < 0.05 = 0.16 Within P < 0.05 = 0.32
Means P < 0.01 = 0.22 Table P < 0.01 = 0.43

There were no significant differences in capsule morphine between the various lengths of immersion although at the second and third time of harvest the trend was for lower capsule morphine as the period of immersion increased.

Table 22. Morphine in the immersion water after the second and third harvest (mg).

Length of Immersion (minutes)	Time of Harvest (weeks after full bloom)			Immersion Means l.s.d.	
	4	6	Mean	P< 0.05	P< 0.01
6.7	0.01	0.09	0.06	0.19	0.26
44.8	0.04	0.10	0.07		
300	0.37	1.23	0.80		
Mean	0.14	0.47			

l.s.d. Time P<0.05 = 0.15 within P<0.05 = 0.26
Means P<0.01 =).21 Table P<0.01 = 0.36

The morphine content of the immersion water at T1 was so low that it could not be measured reliably and was not included in the statistical analysis.

The morphine detected in the immersion water was expressed as the actual weight of morphine in milligrams, not as a percentage of capsule weight because of the low levels involved.

It is apparent that far greater quantities of morphine were detected after the longest immersion time of six than after four weeks. The interaction of Time of Harvest x Length of Immersion was also significant (P<0.01) in that morphine moved more readily from the dry capsule at T3 than T1 or T2 as immersion time increased.

3.3.3. Discussion

In this experiment, although the effect of length of immersion on capsule morphine was not significant, there was a trend towards lower capsule morphine as immersion time increased (Table 21). Other workers

have studied the decline in morphine when capsules become wet by a variety of techniques. In a series of glasshouse experiments using mist sprays as a simulation of overhead irrigation, Bunting (Personal Communication) applied sprays at various times over a six weeks period after full bloom. He found that the greatest decline in capsule morphine occurred when misting was applied over the period 4 - 6 weeks after full bloom compared with any time before this. There were also cultivar differences in the extent of morphine loss but with all cultivars the greatest loss of morphine occurred over this time period. The decrease in capsule morphine compared to non-leached controls ranged from 10% to 50%.

In a field experiment with poppies Loftus Hills (1945) applied an overhead spray irrigation treatment equivalent to 50 mm of rain at various times from petal fall to dry maturity. He found that when the crop was irrigated at dry maturity there was a decline of about 20% in capsule morphine compared with non-irrigated controls. However, in contrast to Bunting's results, losses of morphine of this order also occurred when irrigation was applied to green capsules as early as nine days after petal fall. Here again cultivar differences may be a significant factor as Loftus Hills used cultivars selected for opium production.

The depressions in capsule morphine recorded by Bunting and Loftus Hills when dry capsules were leached six weeks after petal fall are of the same order (i.e. 20% reduction) as the numerical decline recorded for capsule morphine in the present experiment for the longest time of immersion (L3) (Table 21). The morphine detected in the immersion water in the present experiment (Table 22) also supplies corroborative evidence that some morphine did in fact move out of the capsules and that this effect increased with time of immersion.

However it does not necessarily follow that the depression in capsule morphine recorded by Bunting and Loftus Hills were attributable only

to physical leaching and movement of morphine out of the capsule. In neither of their experiments was it possible to measure morphine in the leachate and thus confirm the hypothesis that physical movement of morphine was the unique cause of loss. The simulation used in my experiment is of value from this point of view and allows scope for testing the alternative hypothesis that at least some of the decline in morphine may have been due to chemical or metabolic conversion of morphine within the wet capsule wall. Therefore, if it were assumed that the 20% decline in capsule morphine that occurred after the longest time of immersion (L3) were a real effect in this experiment, then the 1.23 mg detected in the leachate would represent only one quarter of the overall decline in capsule morphine.

In a later laboratory experiment described in Section 6.2. air dried and ground capsule material was wetted and held at 50% moisture for 24 days. Analysis of the moist capsule after this period showed a decline of 11% in morphine compared to ground capsule material held in the air-dried condition. Similarly Kopp (1957) reported that harvested intact capsules stored in a moist atmosphere showed a significant reduction in morphine content. Both of these experiments support the view that some form of chemical conversion of morphine could have occurred within the capsules subjected to the present experimental treatments (Table 21).

In this present experiment (Table 21) the leaching effect was studied with capsules in which the waxy 'bloom' that covered the outer surface of the capsule wall was left intact. This waxy covering may have been of significance in preventing morphine loss in the sense that it was water repellent. In the field it has been observed that loss of this waxy material can occur from certain areas of the capsule by contact and abrasion between neighbouring plants in windy weather.

The sharp edges of the stigmatic rays at the top of the capsule can easily scratch the walls of neighbouring capsules (Plate 20).

In a further glasshouse experiment Bunting (Personal Communication) compared the effect of leaching on intact capsules ('non-rubbed') with those from which the waxy bloom had been removed ('rubbed'). When both groups were leached by overhead misting during the period two to four weeks after full bloom, the 'rubbed' capsules were 35% lower in morphine than the 'non-rubbed' capsules and these in turn were no different to the non-leached controls.

3.4. Conclusions

The two experiments on simulated leaching provided evidence that under wet conditions the morphine contents of ground capsules and intact capsules can be lowered. The experiment on intact capsules in particular (3.3.) showed that morphine did move out of the capsule wall and that it was detected as unconverted morphine in the immersion liquid. However this experiment also suggested that some conversion of morphine may have occurred in the capsule wall. The two other workers who have studied this question (Loftus Hills 1945, Bunting 1963) did not measure morphine in the overhead irrigation run off liquid. The contention that some morphine is converted in the capsule wall was also supported by the evidence of the decrease in wet capsule material in experiment 6.2. (Table 41).

4. THE EFFECT OF TIME OF HARVEST ON DRY MATTER AND MORPHINE YIELD

4.1. Introduction

Various European workers have shown that the morphine contents of poppy capsules were higher two or three weeks before dry harvest maturity (Poethke and Arnold 1951, Bunting 1963, Schroder 1965). Other investigations have reported the opposite effect, that capsule morphine concentration increased steadily up to dry maturity (Nikonov 1958 Miram and Pfeifer 1959, Neeger and Schroder 1959). No such detailed information was available for Tasmanian conditions and the very low morphine content of capsules in the 1970/71 season (Table 11) prompted an investigation into this aspect. This is described in section 4.2. below.

The sudden fluctuation of morphine levels of capsules in the Tasmanian environment in 1970/71 also suggested that the alternative of harvesting the whole green plant should be investigated. This type of investigation has been carried out in the European poppy growing areas and very much greater yield of morphine has been shown relative to that derived from capsules (Romisch 1958, Neeger and Schroder 1959, Pfeifer 1962). However in these European studies the individual contributions from main stem and lateral capsules have not been distinguished. Because of this an experiment was designed to study the way in which the dry matter, morphine concentration and yield of all plant components varied between flowering and dry maturity. In addition, this experiment also included a study of the effect of NP fertiliser and fungicidal sprays over the same time period. The method by which this whole experiment was carried out is described below (4.3.) together with the results of time of harvesting per se on the dry matter and morphine yields of various plant components. The results of NP fertiliser on dry matter over time is described in section 5. and various effects of fungi and fungicides in section 6.

4.2. Changes in Capsule Morphine Between Flowering and Dry Maturity

4.2.1. Materials and Methods

A Tasmanian cultivar was sown at Forthside Vegetable Research Farm on 17/8/72 to establish a density of 62 plants/m^2 using a basal fertiliser application of 400 kg/ha 6:14:14 (N P K) pre-drilled and 200 kg/ha lime super with the seed.

At full bloom, plants were selected by the criteria of uniformity of vegetative growth and similarity of the stage of flowering of the terminal capsules to give a uniform population. From these tagged selections, eighteen completely random plants were harvested at approximately weekly intervals commencing seven days after full bloom (mid-December) and continuing till after optimum dry maturity. Plants were left in the field after optimum maturity to reproduce the conditions of harvest delayed by rain.

At each time of harvest three replications of random groups of plants were taken and used for dry weight and morphine determinations. Terminal and lateral capsules were recorded and analysed separately. After the separation of the seed the capsules were oven dried at 95°C, weighed, ground to pass a one mm sieve and analysed for morphine by the method of Pride and Stern (1954).

4.2.2. Results

The dry weight per capsule and morphine concentrations for both terminal and lateral capsules are detailed in Table 23 and morphine concentrations are also shown in Figure 2. It can be seen that after flowering the morphine content of the capsule increased rapidly until a maximum was reached about six weeks after petal fall. After this point the general tendency was for morphine levels to decline with successive harvests. This general pattern of morphine variation with time was similar for both terminal and lateral capsules.

Figure 2.

The effect of time of harvest after full bloom on the morphine content of terminal and lateral capsules

● = Terminals; O = Laterals

L.S.D.

	Terminals	Laterals
$P < 0.05$	0.21	0.38
$P < 0.01$	0.28	0.52

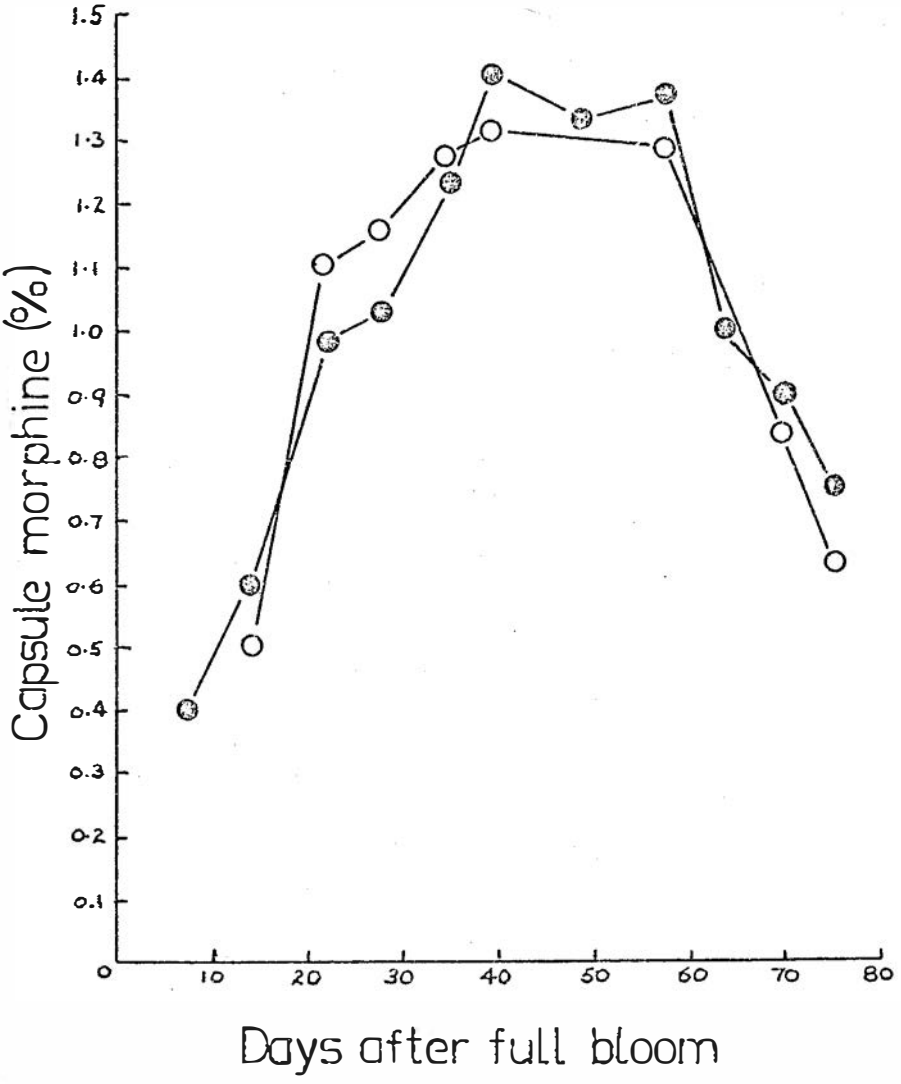

Capsule morphine (%)
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
60
70
80
Days after full bloom

Table 23. The effect of time of harvest on the dry weights and morphine concentrations of capsules

Harvest No.	Harvest time Days after full bloom	Dry Weight/Capsule(g) Terminal	Mean Capsule Morphine(%) Terminal	Lateral
1	7	2.00	0.40	-
2	14	2.38	0.61	0.50
3	23	1.96	0.97	1.09
4	29	1.99	1.04	1.17
5	36	2.29	1.24	1.27
6	41	2.33	1.40	1.32
7	50	2.17	1.31	-
8	57	1.93	1.37	1.29
9	64	1.84	1.02	-
10	71	2.19	0.89	0.84
11	77	2.06	0.75	0.62
L.S.D.	P< 0.05	N.S.	0.21	0.38
	P<.0.01		0.28	0.52

4.2.3. Discussion

The pattern of morphine accumulation and depletion in the capsule of the oil poppy in this experiment was very similar in general outline to that reported by Bunting (1963) for Southern England. Loftus-Hills (1945) found that, with a limited number of harvest times, capsule morphine appeared to remain constant in two years out of three. Generally then there has been disagreement in the literature.

The crop from which the experimental plants were drawn came to optimum dry harvest maturity and was machine harvested at about the same time as harvest 8. Weather conditions were suitable at commercial harvest time with hot sunny weather in this particular year. But in other seasons

harvest can be delayed by as much as two to three weeks by continued rain and overcast humid weather, and, as seen in Figure 2 morphine levels in the capsule fell steadily over this period after harvest 8.

In this 1972/73 seasons, the crop used for the experiment was not seriously infected by fungi, however in those years when fungal infection is serious, it is when the capsule starts to dry out that infection is most apparent. Therefore the decline in morphine that occurred after harvest 6 in this experiment may be compounded and intensified by fungal effects in certain years. This aspect will be considered in section 6.

The primary aim of this initial experiment was to establish the pattern of morphine concentration in capsules between flowering and maturity. The more detailed investigations into dry matter changes in capsules, seed, stem and leaves together with morphine yields were taken up in 1973/74 season. These are described in section 4.3.

4.3. Changes in Dry Matter and Morphine Yield between Flowering and Dry Maturity

4.3.1. Materials and Methods

The experiment was sown on the 24th August, 1973, at Forthside Vegetable Research Station. The Station is located in the North West Region of Tasmania at Lat. 41° 12' S Long. 146° E, 150 metres above sea level. The soil was a krasnozem with pH of 6.2, available P, 51 ppm, available K 83 m.e./10kg/soil, (See Section 2.2.).

The aspect of the experiment concerning dry matter accumulation and morphine production over time formed part of a larger factorial experiment which also studied the effects of nutrition and fungicidal sprays on dry matter production and fungal colonisation over time. A full 2 x 2 x 2 factorial arrangement of N, P and fungicides was set out in randomised blocks with four replications. Ammonium sulphate (20% N) was the form of nitrogen fertiliser used and this was applied at zero and 100 kg/ha N. Concentrated superphosphate (20% P) was the form of phosphorus fertiliser

and this was applied at zero and 100 kg/ha P. All fertiliser was banded 35 mm below the seed and in addition all P treatments received 10 kg/ha P as normal superphosphate (10% P) mixed in contact with the seed at drilling. After emergence the main plots were thinned to a stand of 50 plants/m^2.

A fungicide spray treatment consisted of 2 kg/ha "Benomyl" (50% active ingredient) + 2 kg/ha "Mancozeb" (80% active ingredient) and this mixture was sprayed at intervals of 10 days from the commencement of flowering till the completion of the experiment approximately one month after dry harvest maturity.

The main plots were 36 metres long and 1.6 metres wide (8 rows at 200 mm) and the effect of time of harvesting was measured by a split plot design in which random sub-plots 1 metre long and 1.2 metres wide (6 rows at 200 mm) were harvested at weekly intervals commencing soon after flowering. The relevant time of harvest data and plant development stages during the course of the experiment are set out in Table 24.

At each harvest the plants were cut off at ground level and the total number and fresh weight recorded for each sub-plot. A random sample of ten plants was then taken and divided into the following components:-

(i) Terminal or main stem heads, separated into capsule material and seed.

(ii) All other lateral heads, separated into capsule material and seed.

(iii) Combined stem plus leaves.

All plant components were oven dried at 95°C and seeds of terminal capsules were also air dried for germination tests.

The samples of terminal capsule, secondary capsule and stem plus leaves components were ground to a particle size < 1 mm. Morphine contents of each component were then determined by the method of Pride and Stern (1954). The morphine content of the whole plants was calculated using a weighted mean of the three constituent components.

The details of this experiment on yield components and morphine production at different times of harvest are based on the mean effects of sprayed and unsprayed plots which received both nitrogen and phosphorus fertiliser mixed and banded together. As there were no interaction effects between fertilisers and time of harvest or fungicide and time of harvest for either total capsules or total plant the effect of time of harvest at this fertiliser combination is indicative of the general effect of time in this experiment.

The assessment of full bloom was carried out daily on two random sub-plots in each of the main plots used in the experiment from the beginning of flowering. Full bloom was then defined as the point when 50% of all terminal and lateral inflorescences had either opened or had formed capsules and dropped their petals.

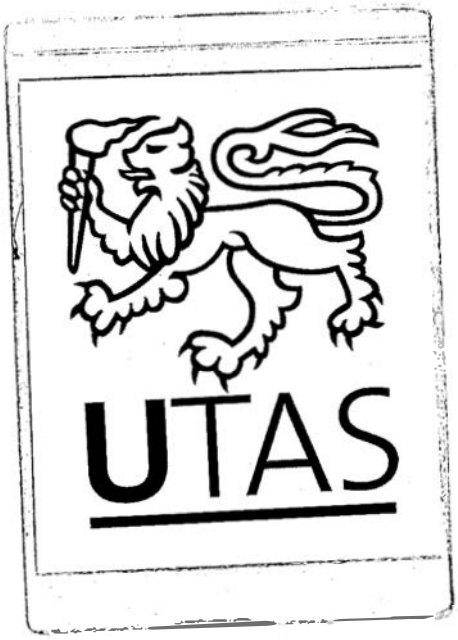


Table 24. The time of harvest together with weekly meteorological data for each individual harvest

Harvest Number	Date of Harvest	Number of Days After Sowing	Number of Days After Full Bloom	Meteorological data during harvesting period: Rain/Week mm	Mean Weekly Temp. C° Min.	Mean Weekly Temp. C° Max.	Visual Capsule Development
H 1	Dec 20 1973	118	10	68	11	20	Green capsule
H 2	Dec 27	125	17	37	9	18	" "
H 3	Jan 3 1974	132	24	33	12	19	" "
H 4	Jan 10	139	31	25	11	20	" "
H 5	Jan 17	146	38	18	12	22	Semi-dry Capsule
H 6	Jan 24	153	45	8	13	21	" " "
H 7	Jan 31	160	52	0	16	25	" " "
ØH 8	Feb 7 1974	167	59	19	12	22	Dry capsule
H 9	Feb 14	174	66	4	12	23	" "
H10	Feb 21	181	73	5	13	22	" "
H11	Feb 28	188	80	1	12	23	" "
*H12	Mar 14 1974	202	94	3	14	23	" "

Ø Commercial dry harvest stage

* Rainfall and temperature figures are the means of 2 weeks

Figure 3.

The effect of time of harvest
after full bloom on the
dry matter percentage of
poppy plant components.
Capsule and seed values are
the means of terminal and laterals.

● = Seed △ = Total Plant

○ = Capsules △ = Stem + leaves

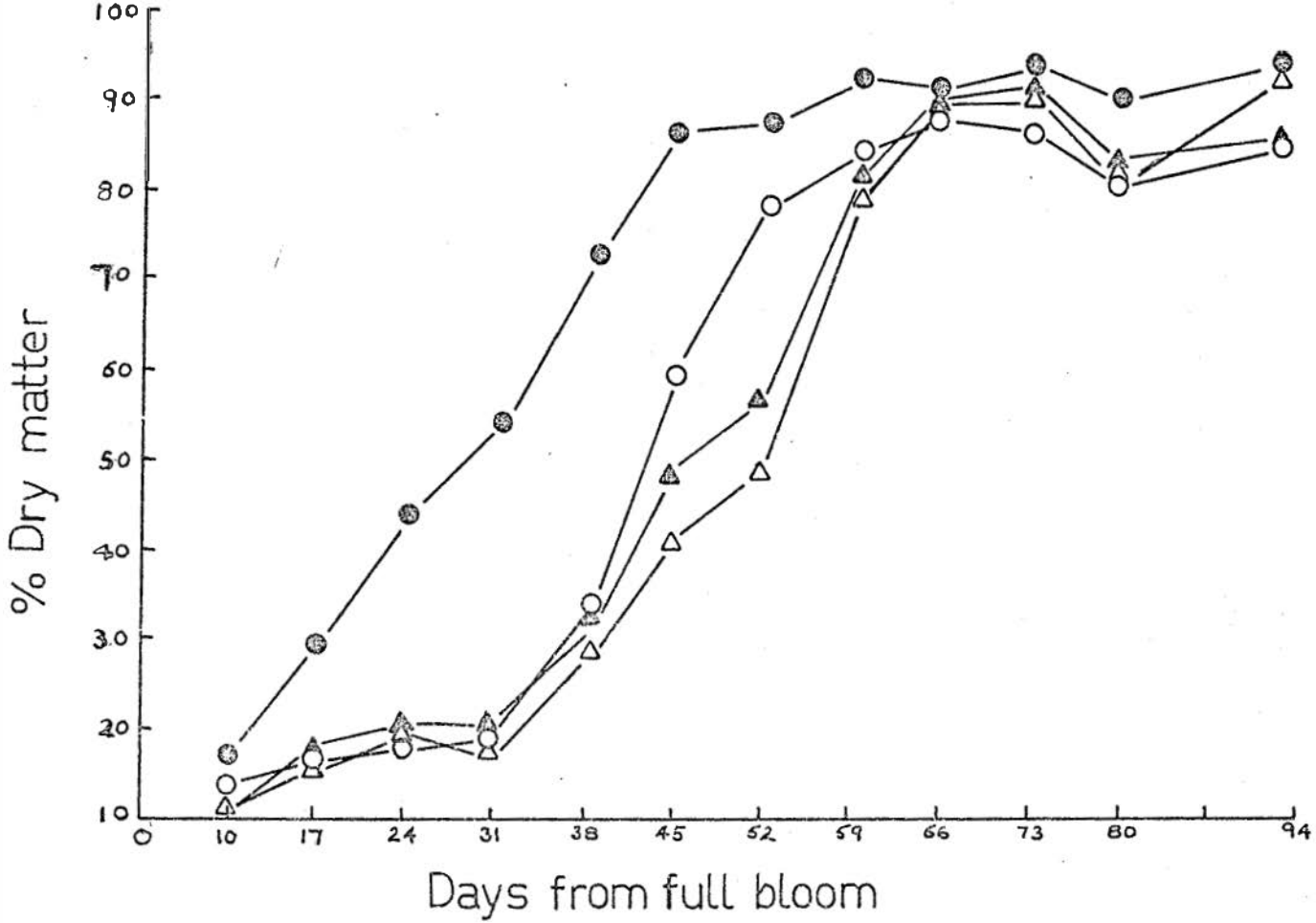

% Dry matter
100
90
80
70
60
50
40
30
20
10
0
10
17
24
31
38
45
52
59
66
73
80
94
Days from full bloom

Plate 2. Poppy capsules harvested four (bottom), five (middle) and six weeks (top) after full bloom. Terminal capsules on left and lateral capsules on right (4.2.).

4.3.2. Results

4.3.2.1. Production of poppy heads

The number of flowers which set and develop into mature sized heads on the poppy plants are controlled by a variety of genetic and cultural factors. Out of the cultural factors, plant density exerts the greatest effect. At the density of 50 plants/m^2 used in this experiment the mean number of 2.2 heads/plant was reached by the second harvest, 17 days after full bloom. Thus each plant had oneterminal or main stem head and a mean of 1.2 lateral heads.

4.3.2.2. Changes in capsules

The percentage of dry matter in all capsules remained at a low level of less than 20% during the first 30 days after full bloom. After this there was a rapid loss of water from the capsules and within the next two to three weeks the percentage of dry matter rose very rapidly to approximately 85% (Figure 3). This level was then maintained for the duration of the experiment.

In contrast to the percentage content of dry matter, the yield of dry matter reached a maximum between the second and third week following full bloom. This was six weeks before commercial harvest (H8) when the dry matter yield of terminal capsules was 37% less than the maximum (Table 25).

The changes in percentage dry matter of lateral and terminal capsules were essentially similar but the dry matter yield pattern of lateral capsules contrasted with that of the terminals. Although the maximum yield pattern of laterals was reached at the same time as that of terminals there was no significant change in lateral capsule yield between H2 and H8, whereas terminal capsule yields fell progressively after H2. However, because of the relatively greater yield of terminal capsules at all times of harvest, the overall total capsule yield pattern followed that of terminals quite closely. Thus the total capsule dry matter yield at commercial harvest was 29% less than at H2 (Table 25).

Table 25. The effect of time of harvest on dry matter yield, morphine concentration and morphine yield of terminal, lateral and total poppy capsules

Harvest	Days after	Dry matter (kg/ha)			Morphine %			Morphine Yield (kg/ha)		
No.	full bloom	Term.	Lat.	Tot.	Term.	Lat.	Tot.	Term.	Lat.	Tot.
H 1	10	1001	251	1251	0.63	1.03	0.70	6.25	2.48	8.73
H 2	17	1279	667	1946	0.68	0.70	0.68	8.64	4.65	13.29
H 3	24	1115	662	1777	0.71	0.88	0.77	7.88	5.94	13.81
H 4	31	993	652	1646	0.76	0.78	0.77	7.61	5.18	12.79
H 5	38	912	512	1423	1.03	1.04	1.02	9.43	5.21	14.64
H 6	45	873	574	1446	1.08	1.09	1.06	9.39	6.41	15.80
H 7	52	832	584	1415	1.03	1.09	1.06	8.49	6.49	14.98
H 8	59	811	568	1378	0.94	1.00	0.97	7.61	5.78	13.39
H 9	66	765	550	1315	0.84	0.82	0.83	6.50	4.53	11.03
H10	73	832	506	1338	0.90	0.89	0.88	7.51	4.48	11.99
H11	80	730	544	1273	0.79	0.93	0.85	5.75	5.10	10.85
H12	94	729	483	1212	0.83	0.67	0.84	6.18	4.34	10.51
L.S.D.	P<0.05	118	179	233	0.12	0.14	0.10	1.47	N.S.	3.27
	P<0.01	156	235	307	0.16	0.16	0.14	1.95	N.S.	4.34

Because of the relatively close agreement between the morphine concentration of terminal and lateral capsules, the composite morphine concentration of total capsules followed a similar trend. This value reached a maximum at H6 and there was a small decline to H8 followed by a further decline until the end of the experiment (Table 25.)

The morphine yield of terminal capsules reach a maximum approximately two weeks before dry commercial harvest (Table 25). However the morphine yield of lateral capsules differed markedly in that there were no

significant differences between any of the times of harvest. This is mainly attributable to the pattern of dry matter production of lateral capsules which changed little between H2 and H8. In contrast to terminal capsules and due to the impact of laterals the total capsule morphine yield had not declined significantly at H8.

4.3.2. 3. Changes in seed

The seeds of the poppy differed markedly from capsules and all other plant components in that they either do not contain morphine (Fairbairn & El Nasry 1967) or arguably contain it in minute quantities of 3 p p m (Grove et al 1976). In contrast to capsule tissue also the percentage dry matter of both terminal and lateral seeds increased rapidly from the time of the first harvest (Figure 3). In addition between H1 and H3 the seed underwent many striking colour variations in changing from the initial white to various shades of rust to brown then grey-blue. During the next three to four weeks up to H6 the colour of the seed progressively deepened to the final mixture of light and dark blue. (Plate 4).

By H3 the seed from terminal capsules already had a laboratory germination of 85% and total seed dry matter reached a maximum yield at H4 when it had a dry matter content of about 50%. Once achieved, maximum total seed yield remained constant until H12 (Table 26). Dry matter yield of seed thus contrasted with the capsule and stem and leaf component in its later maximum (H4 compared with H2) and the fact that this yield had not decreased by the time of commercial harvest.

Plate 3. Longitudinal section of a poppy capsule two weeks after full bloom. The parietal placentation of the white immature seeds is shown and the method of attachment to the loculi.

Plate 4. The four samples illustrate the changes in seed colour which occurred during the first four weeks after full bloom. Immature white (top left) followed by rust shade (top right), colours deepening (bottom left) to final grey blue (bottom right). (4.3.2.3.)

Table 26. The effect of time of harvest on dry matter yield of terminal lateral and total oil poppy seed

Harvest Number	Days after Full bloom	Seed Yield (kg/ha) Terminal	Lateral	Total
H 1	10	405	37	442
H 2	17	892	234	1127
H 3	24	1126	362	1488
H 4	31	1470	460	1929
H 5	38	1505	494	2000
H 6	45	1406	714	2120
H 7	52	1339	730	2069
H 8	59	1326	774	2099
H 9	66	1282	668	1950
H10	73	1510	676	2186
H11	80	1232	572	1803
H12	94	1222	695	1917
L.S.D.	P< 0.05	199	273	350
	P < 0.01	261	358	460

4.3.2.4. Changes in stem and leaves

The percentage dry matter of stem and leaves was comparable with that of capsules in that it was 20% or less for the first 30 days following full bloom (Figure 3). After this there was an accelerated loss of water from stem and leaves but the rate of loss was not as great as with the capsules (Figure 3).

The pattern of dry matter accumulation in stem and leaves closely followed that of terminal capsules. Thus the maximum yield of the stem and leaf component was also achieved two to three weeks after full bloom. After

this, yields declined progressively until at H8 the mean yield was 39% less than that reached five to six weeks earlier (Table 27).

The relative morphine concentration in stem and leaves was generally very much lower than in capsules but the maximum level of about 0.1% was reached about the same time as the much higher level of 1.1% in capsules. However the changes in morphine concentration of stem and leaves at the later harvests contrasted strongly with those in capsules. Thus between H6 and H8 the morphine concentration in stem and leaves halved while the level in total capsules fell by only about 10% (Tables 25,27).

Although the morphine percentage of stem and leaves was relatively low compared with capsules the yield of morphine from this components was quite considerable because of its large dry matter yield. At H1 it virtually equalled capsule morphine but it differed from capsules in that stem + leaf morphine yield dropped sharply between H6 and H8 (Table 27).

4.3.2.5. Changes in total plant

The percentage dry matter content of the total plant followed very closely the percentage content of stem and leaf components (Figure 3). This was because of the great bulk of dry matter yield from stem and leaves relative to any other plant components (Tables 25, 26, 27). Therefore, because of the predominating influence of stem and leaves and total capsules,

Table 27. The effect of time of harvest on mean dry matter yield, morphine concentration and morphine yields of stem and leaves

Harvest Number	Days after full Bloom	Dry matter (kg/ha)	Morphine (%)	Morphine Yield (kg/ha)
H 1	10	8420	0.09	7.86
H 2	17	9042	0.06	4.91
H 3	24	8440	0.09	7.46
H 4	31	7227	0.08	5.49
H 5	38	6738	0.10	6.40
H 6	45	6832	0.08	5.06
H 7	52	6469	0.06	3.65
H 8	59	5516	0.04	2.20
H 9	66	5866	0.05	2.03
H10	73	5727	0.03	3.03
H11	80	5784	0.04	2.40
H12	94	4160	0.06	2.33
L.S.D.	P< 0.05	1037	0.02	1.80
	P < 0.01	1363	0.03	2.39

Table 28. The effect of time of harvest on dry matter yield, morphine concentration and morphine yield of total plant

Harvest Number	Days After Full Bloom	Dry Matter (kg/ha)	Morphine % (+ seed)	Morphine % (- seed)	Morphine Yield (kg/ha)
H 1	10	10112	0.16	0.17	16.59
H 2	17	12112	0.15	0.17	18.20
H 3	24	11706	0.18	0.21	21.25
H 4	31	10808	0.17	0.21	18.26
H 5	38	10153	0.21	0.26	21.05
H 6	45	10524	0.20	0.25	20.26
H 7	52	9952	0.19	0.24	18.63
H 8	59	9002	0.17	0.23	15.59
H 9	66	9121	0.15	0.19	14.03
H10	73	9267	0.15	0.20	14.01
H11	80	8869	0.15	0.19	13.25
H12	94	7304	0.17	0.23	12.84
L.S.D.	P < 0.05	1516	0.02	0.03	3.98
	P < 0.01	1992	0.03	0.05	5.28

both of which reached a maximum dry matter yield at H2, the yield of total plant also reached a maximum at this time. At dry commercial harvest the yield of total plant was 26% less than that achieved six weeks earlier.

The morphine concentration of total plant in Table 28 is expressed in the presence and absence of seed. As the morphine content of poppy seed is either nil or negligible the morphine concentration of the whole plant will vary depending upon whether seed is separated prior to measurement. In the earlier harvests, during the green phase, seed separation was difficult and impossible at a practical level. However from H6 onwards

as both seed and capsule dried out rapidly, the separation of seed was accomplished much more easily. The expression of morphine concentration of total plant inclusive and exclusive of seed then covers both of these situations.

In either situation the morphine concentration of total plant tended to reach a peak about H5 or H6. In this it reflected the pattern of morphine accumulation in total capsules and despite the relatively high levels of stem and leaves at earlier harvests the morphine concentration of capsules had the deciding influence. At commercial harvest and later, the morphine concentration of total plants was in a declining phase (Table 28).

The morphine yield of total plant at H6 was 30% greater than that at H8 but there were no significant differences in total morphine yield between any of the harvests for H2 to H6. However there were tremendous differences in fresh yield of total plant over the same period with fresh harvested yields ranging from approximately 77 t/ha down to 22 t/ha (Table 29). At H6 the fresh yield of total plant was approximately five times the fresh yield of poppy heads at H8 but the morphine yield from total plant at H6 was 55% greater than the morphine yield from capsules at H8.

Table 29. The yield of morphine derived from total plant and its components with their respective fresh harvested yields.

Harvest Number	Days After Full Bloom	Morphine (kg/ha)			Fresh Yield (t/ha)		
		Total plant	Total Capsules	Stem + Leaves	Total plant	Total head	Stem + Leaves
H 1	10	16.59	8.73	7.86	82.9	11.2	71.7
H 2	17	16.20	13.29	4.91	77.3	15.8	61.5
H 3	24	21.25	13.81	7.46	57.1	13.7	43.4
H 4	31	18.28	12.79	5.49	55.9	12.6	43.3
H 5	38	21.05	14.64	6.40	31.1	7.0	24.0
H 6	45	20.86	15.80	5.06	21.7	5.1	16.7
H 7	52	18.63	14.98	3.65	17.7	4.1	13.6
H 8	59	15.59	13.39	2.20	11.3	3.9	7.4
H 9	66	14.05	11.03	2.03	10.2	3.6	6.6
H10	73	14.01	11.99	3.03	10.3	3.9	6.4
H11	80	13.25	10.85	2.40	10.7	3.6	7.1
H12	94	12.84	10.51	2.33	8.7	3.5	5.2
L.S.D.	P< 0.05	3.98	3.27	1.80	7.0	1.5	5.7
	P < 0.01	5.28	4.34	2.39	9.2	2.0	7.5

4.3.3. Discussion

4.3.3.1. Dry matter yields

Under the climatic conditions in the poppy growing area of the North West Region of Tasmania, dry capsules are commercially harvested about eight weeks after full bloom. At this time (H8) a salient feature of this experiment was the way that dry matter yields of terminal capsules and

the stem and leaf component had declined from their former maxima established six weeks earlier. By the time of dry commercial harvest terminal capsules were 37% less and stem and leaves 39% less and this gave a decrease of 26% in total plant over the same period. Other workers have recorded similar depressions in dry matter yield of either the total poppy plant or some of its components between flowering and maturity. Romisch (1958) found a 35% decline in total plant dry matter yield while Heeger and Schroder (1959) found a 12% fall in total plant, 22% in stem and leaves and 40% in capsules dry matter yield. Both Bunting (1963) and Schroder (1965) have recorded depressions of up to 25% in capsule dry matter with some cultivars over this period. Subsequent field experiments in Tasmania have also shown that the individual stem and leaf components harvested separately both decline in dry matter yield over this period to a similar extent as the composite stem and leaf component in this experiment (Chung, Personal Communications).

This nett pattern of dry matter changes in the total yield of the poppy after flowering seems to be unusual and contrasts with a number of other crops such as maize (Zea mays L.) and rice (Oryza sativa L.). In the case of both maize (Hume and Campbell 1972, Duncan 1975) and rice (Murata and Matsushima 1975) total plant yield increased right up to dry harvest maturity primarily due to continuing increases in head and grain yield in these two crops. However both crops were similar to the poppy in that the dry matter yield of the stems of both plants decreased by 20 - 25% in dry matter yield in the post flowering period.

Some Russian experiments suggest that the poppy capsule at least is the centre of intense physiological activity after flowering. Prokofiev and Codneva (1957) have shown that the photosynthetic activity of poppy capsules for 10 to 12 days after flowering was equal to that of the leaves of the central stem region. Prokofiev and Kats (1961) also showed that transpiration was greater in capsules than in leaves. Physiological

studies with other oil seed crops may provide instructive comparisons and suggest aspects which could help explain the dry matter changes in the poppy in the post-flowering period. Various studies with oil seed rape (Brassica rapus L.) have shown that both the pods and stem make significant contributions to whole plant photosynthesis at full bloom and afterwards (Allen et al 1971, Inanaga and Kumura 1974). In particular Inanaga and Kumura showed that the respiration rate of stem and pods was high and that the respiration: photosynthesis ratio increased as the plant matured after flowering. This ratio may also be typically very high in the stem and capsules of the poppy in the post-flowering period and thus contribute to dry matter yield decreases.

Another physiological aspect of the oil poppy which may throw light on the decrease in dry weight after flowering is the relative efficiency with which it converts the translocated products of photosynthesis to structural compounds and accumulates oil in its seeds. On this point Penning de Vries (1972, 1974) ranks oilseeds generally as more efficient than cereals or legumes. But the literature on this area is sparse and despite the average efficiency of oilseed crops in general it may well be that oil poppies are a special case. This could be particularly so in the case of the oil poppy strains which have been selected for high morphine in the capsule rather than for seed production as was the case of the cultivar used in this experiment. Plants such as this may have a very low efficiency of conversion to poppy seed oil and drastically deplete carbohydrate reserves in the process.

4.3.3.2. The yield and maturity of poppy seed

In this experiment the moisture content of the seeds of all capsules started to decrease rapidly 10 days after full bloom in contrast to and independent of the surrounding capsule tissue (Figure 3). The seed ripening pattern in this experiment was therefore very similar to that recorded by Bunting (1963) for drier seasons in southern England and that found

in Russian experiments by Prokofiev and Kholodova (1968).

The development of maximum dry matter yield of total seed at about 30 days after full bloom is also consistent with Bunting's results for seed from terminal capsules (Table 26).

This final dry matter yield of seed initially occurred at H4 when its dry matter content was approximately 55%. Two weeks later at Harvest 6 the dry matter content of seed had reached 85% when the dry matter content of capsules was only 60%. Both of these factors of seed yield and dry matter content are very pertinent to any consideration of alternative methods of harvesting at any time prior to dry commercial harvest since the seed is a valuable by-product in the Tasmanian cultural system. Therefore these results indicate that if whole plants or capsules were taken at H6, for example, a significant proportion of the seed could probably be separated either before or after artificial drying.

4.3.3.3. The yield of morphine

The most obvious difference between the results of this experiment and those of similar European studies was the fact that maximum total plant morphine yield was sustained over a period of five to six weeks from H2 (Table 28). This contrasted strongly with the sharp peak of total plant morphine yield which occurred during the green stage in these European studies. In East Germany, Romisch (1958) found that maximum total plant morphine yield occurred 4 weeks before dry harvest maturity. Haeger & Schroder (1959) and Pfeifer & Heydenreich (1962) concluded similarly that it occurred three to four weeks before dry harvest. In addition some earlier, less detailed studies with opium type cultivars in Australia (Loftus Hills 1945) and in the Soviet Union Republic of Kirghizia (Nikonov 1958) also suggested that total plant morphine was at a maximum while the plant was green.

It has been pointed out by Bunting (1963) that comparisons of times of poppy harvest between different environments are difficult to make unless

moisture contents are specified. In the case of the experiment of Romisch (1958) the maximum total plant morphine yield occurred at a total plant dry matter content of about 16% while Neeger & Schroder (1959) found maximum morphine at 14% and 23% in different years. Pfeifer & Heydenreich (1962) do not give specific dry matter contents but their description suggests that maximum total plant morphine occurred at a comparable stage to the other East German workers quoted. In this Tasmanian experiment total plant morphine was sustained up to a total plant dry matter content of approximately 50% which occurred at H6 (two weeks before dry harvest maturity). In particular the results of the experiment of Romisch (1958) are strikingly different from the Tasmanian results. In Romisch's experiment with the cultivar Mahndorfer both the total plant morphine concentration and total plant morphine yield had decreased greatly by the dry commercial capsule stage. At this time the morphine concentration was only one-half and the morphine yield only one-third of their former maxima, established four weeks earlier.

The fact that maximum total plant morphine persisted in this experiment to a much lower moisture content than those quoted in the European experiments could be of considerable practical importance. At H6 or two weeks prior to the average time of commercial ripe capsule harvest, the poppy plant is drying out very quickly in the Tasmanian environment (Figure 3). This aspect is very important in any consideration of the practical feasibility of extracting morphine from the whole plant or from green capsules both with respect to the cost of transport and the cost of drying.

Persistence of maximum total plant morphine yield up to two weeks prior to commercial harvest in this experiment was attributable to a number of factors. Firstly the high morphine concentration of both terminal and lateral capsules did not reach a peak level until H6 (Table 25). Thus the rate of increase in total capsule morphine concentration up to H6 offset the decrease in dry matter yield of total capsules and hence maximum total

capsule morphine yield persisted (Table 25). In this experiment, lateral capsules contributed 40% of the morphine coming from overall capsule input and the concentration of morphine from lateral capsules equalled that of terminal capsules at H6. This is in contrast to the work of Kleinschmidt & Mothes (1958) who found that lateral capsules were 20% lower in morphine concentration than terminal capsules. Secondly the morphine yield contribution from the stem and leaf component followed a somewhat similar pattern to that from capsule sources in that it remained virtually constant up to H6. But between this point and H8 the morphine yield of stem and leaves fell to less than half its former value, primarily due to a 50% decline in morphine concentration (Table 27).

The relative yields of morphine obtained in this experiment by harvesting whole plants or capsules can be compared with the results of similar European studies. In particular a comparison can be made between the morphine derived from whole plants harvested at peak morphine yield with that derived from capsules alone, harvested at dry commercial maturity. This ratio was 1.5 : 1 in favour of whole plants in this Tasmanian experiment and it may be compared with ratios of 4 : 1 obtained by Romisch (1952) and 2 : 1 by Heeger & Schroder (1959).

Generally then the relative advantage of harvesting the whole plant or green capsules with some proportion of stem is less in Tasmania than in the European studies. However the later development of maximum morphine in the Tasmanian environment and the resulting lower fresh matter yield could be a practical advantage (Table 28). If harvesting of the green plant or its components were undertaken then the use of plant desiccants could be a method of decreasing the fresh harvested weight. Potin & Segal (1968) used paraquat, diquat and magnesium chlorate to desiccate poppies in Russian experiments and this did not reduce seed yield, germination or the morphine content of capsules.

Similarly in Yugoslavia, Gozevac (1953) found that if poppy capsules were harvested while green the yield of seed and oil was only

slightly reduced.

4.4. Conclusions

In both experiments 4.2 and 4.3 in which the capsules were sequentially harvested between flowering and maturity there was a common pattern. Morphine concentration of capsules built up to a maximum about six weeks after full bloom. However in experiment 4.2., carried out through the wet harvesting season of 1972/73, morphine concentration declined much more sharply after the maximum had been reached. Therefore in wet years, poppy crops would probably experience serious losses of morphine if left standing in the field long after optimum maturity.

When the whole plant was divided into its components in the experiment of 1973/74 the yield of all components except seed reached a maximum about two weeks after full bloom and thendeclined successively towards dry harvest maturity. The mutually compensating factors of decreasing dry matter yield and increasing morphine concentration gave similar total plant morphine yields at any time of harvest from two to seven weeks after full bloom. The morphine extracted from the whole plant at these times of harvest was about 55% greater than that derived from capsules alone at the time of dry commercial harvest. (Experiment 4.3.).

5. THE EFFECT OF NP NUTRITION ON DRY MATTER YIELD AT DIFFERENT TIMES OF HARVEST

5.1. Introduction

In section 2.3. and 2.4. of this thesis it has been shown that N x P interaction effects occurred in terms of capsules, seed and morphine yield when the plant was harvested at dry maturity. In these experiments the various NP fertiliser combinations were banded either by pre-drilling or by placing directly under the seed. No Tasmanian experiments had studied the effect of these banded N P fertilisers on the whole poppy plant or its components harvested in the green stage nor did any appear to have been reported in the literature. Therefore when the experiment of harvesting the plant green for morphine extraction was considered, the aspect of N P nutrition was included as one of the important variables.

The object of this phase of the overall studies was therefore to assess the effect of combinations of banded N and P fertiliser on dry matter yield of total plant and its various components when harvested at weekly intervals between full bloom and one month after dry maturity.

5.2. Materials and Methods

The detailed description of the experimental method has already been given in section 4.3., however some of the more salient features of the fertiliser rates are repeated here. Ammonium sulphate was applied at N0 = zero and N1 = 100 kg/ha N and concentrated superphosphate (20% P) at P0 = zero and P1 = 100 kg/ha P. In addition all the P treatments received 10 kg/ha P as normal superphosphate (10% P) mixed in contact with the seed at drilling. In addition to the weekly harvests taken after flowering two additional harvests of the complete young plant (excluding roots) were taken eight weeks and twelve weeks after sowing. The experimental site was a krasnozem of pH 6.2, available phosphorus 51 p.p.m. P, and available potassium 83 m.e./10 kg soil (Colwell 1965. See section 2.2.1.).

5.3. Results

5.3.1. Early growth responses

The application of nitrogen fertiliser banded with phosphorus had a marked impact on dry matter yield in the earlier stages of growth. However it can be seen from Tables 30 and 31 that the effect of N depended very much on the level of P at which it was applied. At the zero level of P, nitrogen had a depressing effect on yield at eight weeks and produced a comparatively small growth response at twelve weeks. In the presence of P, nitrogen gave a 43% increase in dry matter yield at eight weeks and a 74% increase at twelve weeks. This pattern of yields gave marked N x P interaction effects which were significant ($P < 0.01$) at both times of harvest.

Plates 6, 7, 8 and 9 also illustrate the visual impression of these treatments at the ten weeks stage of growth.

Table 30. The effect of banded N and P fertilisers on dry matter yield of whole plants eight weeks after sowing (kg/ha).

	P0	P1	Mean
N0	25	64	45
N1	21	95	58
Mean	23	80	

l.s.d. fertiliser means
$P < 0.05 = 6$
$P < 0.01 = 9$

l.s.d. within Table 30
$P < 0.05 = 9$
$P < 0.01 = 13$

Table 31. The effect of banded N and P fertiliser on dry matter yield of whole plants twelve weeks after sowing (kg/ha).

	P0	P1	Mean
N0	708	1643	1176
N1	804	2871	1838
Mean	756	2257	

l.s.d. fertiliser means
$P < 0.05 = 157$
$P < 0.01 = 225$

l.s.d. within Table 31
$P < 0.05 = 222$
$P < 0.01 = 328$

Plate 5. A general view of the "stringing" method of splitting main fertiliser plots into sub plots for yield measurements at various times of harvest.

Plate 6. Nil fertiliser plots showing low relative vegetative growth ten weeks after sowing.

Plate 7. N fertiliser plots with plant vigour about equal to a nil fertiliser plot on the left (see also Plate 6 above) at the ten week stage.

Plate 8. Plots with P fertiliser made quick early growth relative to nil fertiliser (Plate 6) or N alone (Plate 7) at the ten week stage.

Plate 9. N + P fertiliser plots at the ten week stage showed obvious visual improvement over P alone (Plate 8).

5.3.2. Number of capsules per plant

In Table 32 the number of capsules per plant is set out as a mean over twelve times of harvest. It can be seen that the general pattern of response is similar to that of early dry matter accumulation in that there was a small increase due to nitrogen at zero level of P0, a 30% increase at P1 and an N x P interaction. All effects were significant at the $P < 0.01$ level.

Table 32. The effect of banded N and P fertiliser on the mean numbers of capsules per plant.

	P0	P1	Mean
N0	1.42	1.67	1.55
N1	1.54	2.17	1.86
Mean	1.48	1.92	

l.s.d. fertiliser means	l.s.d. within Table 32
$P < 0.05 = 0.07$	$P < 0.05 = 0.10$
$P < 0.01 = 0.10$	$P < 0.01 = 0.14$

5.3.3. Fertiliser effects on capsule yield

In the case of terminal, lateral and total capsule yields there were no interactions between time of harvest and fertilisers nor between fertilisers and the spray treatment. Because of this the effects of N and P fertiliser set out in Tables 33, 34 and 35 below are the means of the sprayed and non-sprayed treatments themselves meaned over twelve times of harvest. In effect then, the mean capsule yields set out in these tables are indicative of the general effect of fertiliser at any time of harvest. This observation vis-à-vis capsules also applies generally to stem + leaves (Table 39) and total plant (Table 40) but not to seed yield (Tables 36 and 38).

5.3.3.1. Terminal capsules

There was a significant ($P < 0.05$) depressing effect of P on terminal capsule yield and no effect of N. In the case of terminal capsules there was also a time of harvest x spray x P interaction which was barely significant. This was mainly attributable to variations in the spray effect at the earlier harvest and does not substantially affect the assumptions as to the generalised effect of fertiliser.

Table 33. The mean effect of banded N and P fertiliser on dry matter yield of terminal capsules (kg/ha).

	P0	P1	Mean
N0	963	939	951
N1	951	906	929
Mean	957	923	

l.s.d. fertiliser means

$P < 0.05$ = 32

$P < 0.01$ = 43

5.3.3.2. Lateral capsules

The effect of N and P on lateral capsules contrasted strongly with the effect on terminals in that there was a large yield increase ($P < 0.01$) due to both of these elements and a significant ($P < 0.05$) N x P interaction. Although this pattern of dry matter yield was partly a reflection of the impact of fertiliser on capsule numbers there was also another effect on weight per capsule. As seen in Table 32, N1 applied at P1 gave a 30% increase in capsule numbers over N0 at P1 but N1 gave a 57% increase in dry matter yield of lateral capsules for the same comparison in Table 34.

Table 34. The mean effect of banded N and P fertiliser on dry matter yield of lateral capsules (kg/ha).

	P0	P1	Mean
N0	234	348	291
N1	293	546	420
Mean	264	447	

l.s.d. fertiliser means
P < 0.05 = 42
P < 0.01 = 57

l.s.d. within Table 34
P < 0.05 = 59
P < 0.01 = 81

5.3.3.3. Total capsules

The effect of fertiliser on total capsules was conditioned by the small depressing effect of P on terminal capsules (Table 33) and the large yield increase of P with lateral capsules (Table 34). There were therefore significant mean effects (P < 0.01) of both P and N and because the effect of P is much more marked at N1 than N0 there was also an N x P interaction (P < 0.05) (Table 35).

Table 35. The mean effect of banded N and P fertiliser on dry matter yield of total capsules (kg/ha).

	P0	P1	Mean
N0	1197	1286	1242
N1	1243	1452	1348
Mean	1220	1369	

l.s.d. fertiliser means
P < 0.05 = 54
P < 0.01 = 73

l.s.d. within Table 35
P < 0.05 = 76
P < 0.01 = 103

5.3.4. Fertiliser effects on seed yield

5.3.4.1. Seed from terminal capsules

The yield of seed from terminal capsules was affected by both time of harvest x phosphorus and time of harvest x nitrogen interactions. For this reason the mean yields of P0, P1 , N0 and N1 were set out in Table 36 for all times of harvest. The P effects were meaned over all levels of nitrogen and the N effects were meaned over all levels of phosphorus. In contrast to the yields of other plant components, the effect of P was dependent on time of harvest. Up to harvest 5, phosphorus tended to increase yield and after harvest 5 to depress yield of seed from terminal capsules.

The application of nitrogen initially tended to increase yield but after harvest 2 the effect of N was to progressively depress yield. At harvest 3 the mean yield of N1 was 4% less than N0 and by harvest 8 mean seed yield of N1 was 17% less than N0. This may be compared with a similar but lesser depressing effect of P of 11% at harvest 8.

Table 36. The effect of fertiliser treatment and time of harvest on the mean dry matter yield of seed from terminal capsules (kg/ha).

Harvest Number	Days from Full Bloom	P0	P1	N0	N1
H1	10	248	340	259	329
H2	17	741	885	803	823
H3	24	1137	1211	1195	1153
H4	31	1385	1446	1468	1362
H5	38	1542	1579	1624	1496
H6	45	1523	1500	1614	1409
H7	52	1597	1487	1630	1454
H8	59	1649	1472	1709	1412
H9	66	1653	1442	1668	1427
H10	73	1768	1627	1792	1602
H11	80	1431	1407	1548	1288
H12	94	1446	1349	1484	1312
Mean		1343	1312	1399	1256

l.s.d. for fertiliser means of Table 36	$P < 0.05$ =	56
	$P < 0.01$ =	76
l.s.d. within Table 36 for comparing	$P < 0.05$ =	222
yields of different fertiliser levels	$P < 0.01$ =	293
either at any one time of harvest or at two different times of harvest		
l.s.d. within Table 36 for comparing	$P < 0.05$ =	140
yields of any two times of harvest at any one fertiliser level	$P < 0.01$ =	185

The calculations of standard errors and t values used for computing l.s.d. figures for comparisons of means and values within Table 36 followed the method set out by Cochran and Dox (1966) for split plot designs.

5.3.4.2. Seed from lateral capsules

In contrast to terminal seed yield the yield of seed from lateral capsules was not affected by time of harvest x fertiliser interactions. For this reason the effects of fertiliser could be expressed in Table 37 as the means of sprayed and non-sprayed treatments themselves meaned over the twelve times of harvest. Phosphorus had a mean effect of increasing yields of lateral seed by 44% ($P < 0.01$) and nitrogen increased lateral seed yield by 20% ($P < 0.05$).

The yield of seed from lateral capsules was affected by the initial impact of fertiliser on capsule numbers (Table 32). However this effect differed to some extent from that on lateral capsules themselves (Table 34). When N1 was applied at P1 there was a 23% increase in yield of seed compared with N0 at P1 but the increase in capsule numbers per plant was 30% and in capsule yield 57% for the same comparisons. Therefore nitrogen decreased the weight of seed per capsule but increased the weight of individual lateral capsules.

Table 37. The effect of banded N and P fertiliser on dry matter yield of seed from lateral capsules (kg/ha).

	P0	P1	Mean
N0	311	433	372
N1	361	534	448
Mean	336	484	

l.s.d. fertiliser means
$P < 0.05 = 58$
$P < 0.01 = 79$

5.3.4.3. Total seed yield

The various factors influencing the yield of seed from terminal and lateral capsules had a nett compounded effect of giving a marked yield increase with phosphorus but a spray x N interaction. For this reason Table 38 sets out the mean yield of twelve times of harvest in the sprayed and non-sprayed situation in addition to the effect of P meaned over sprayed and non-sprayed plots.

Phosphorus fertiliser had a significant ($P < 0.01$) effect in either the sprayed or non-sprayed treatments. But although nitroger had little effect in the sprayed treatments it had a significantly depressing effect ($P < 0.05$) in the non-sprayed treatments.

Table 38. The effect of fertiliser and spray treatments on the dry matter yield of total seed (kg/ha).

	P0	P1	Mean	Spray	Non-sprayed	Mean
N0	1712	1829	1771	1808	1734	1771
N1	1645	1760	1703	1837	1568	1703
Mean	1679	1800				

l.s.d. fertiliser means
$P < 0.05 = 80$
$P < 0.01 = 110$

l.s.d. spray x N effect within Table 38
$P < 0.05 = 114$
$P < 0.01 = 155$

5.3.5. Fertiliser effects on stem and leaves

The effect of fertiliser on the yield of stem and leaves followed the pattern found with capsules in that there were highly significant effects of N and P ($P < 0.01$) and a significant N x P interaction ($P < 0.05$). There was also a time of harvest x spray x P interaction which will be discussed in Section 6 of this thesis but which did not alter the basic pattern of N and P responses set out in Table 39.

Table 39. The effect of banded N and P fertiliser on dry matter yield of stem and leaves (kg/ha)

	P0	P1	Mean
N0	5031	5670	5351
N1	5381	6687	6034
Mean	5206	6179	

l.s.d. fertiliser means	l.s.d. within Table 39
$P < 0.05$ = 276	$P < 0.05$ = 390
$P < 0.01$ = 376	$P < 0.01$ = 531

5.3.6. Fertiliser effects on total plant

Because of the dominating influence of total capsules and stem + leaves the effect of fertiliser on total plant yield was predictably the same as that already shown for these two components. That was, a highly significant effect ($P < 0.01$) of both N and P and a significant ($P < 0.05$) N x P interaction.

Table 40. The effect of banded N and P fertiliser on mean dry matter yield of total plant (kg/ha)

	P0	P1	Mean
N0	7948	8785	8367
N1	8273	9910	9092
Mean	8111	9348	

l.s.d. fertiliser means	l.s.d. within Table 40
$P < 0.05$ = 375	$P < 0.05$ = 530
$P < 0.01$ = 510	$P < 0.01$ = 722

Plate 10. The relative differences between plots without fertiliser (nil on left) and plots with P (on right) had lessened at the stage just prior to flowering (Expt. 5.)

Plate 11. At flowering the height differences between nil (at left) and plots with P (on right) were narrowing. But overall vigour and leafiness of the P treatment were still greater (Expt. 5.)

5.4. Discussion

5.4.1. General

It is quite clear from Tables 30 and 31 that the banded N P combination made a large impact on growth of the poppy in the early stages. Eight and twelve weeks after sowing the N1 P1 treatment gave 48% and 74% greater whole plant dry weight than P1 banded alone (Tables 30 and 31). Later in the ontogeny of the plant and just prior to flowering the plants without phosphorus fertiliser had reduced the large growth discrepancy compared to those with phosphorus (Plate 10). However even on a soil of relatively high available phosphorus and a cultural regime that virtually removed the limiting factors of low soil moisture and competitive weed growth, significant differences were still maintained after flowering (Plate 11).

The primary aim of this aspect of the study was to assess the extent to which N x P interaction effects were expressed when the poppy plant components were harvested in the green stage between flowering and dry maturity. It can be seen from the data of Tables 34, 35, 39 and 40 that there were N x P interaction effects for lateral and total capsules, stem + leaves and total plant. Furthermore there was no interaction between fertiliser and time of harvest for these components and therefore it may be concluded that these mean effects are indicative of the general situation at any of the twelve times of harvest.

Because of the N x P interaction effects which were expressed in this experiment the N1 P1 treatment outyielded the N0 P1 treatment for lateral capsules, total capsules, stem + leaves and total plant by 57%, 13%, 18% and 13% respectively. The effects on terminal capsules and seed yield were more complex and the implications of the patterns of response which were obtained with these components are set out in greater detail below.

5.4.2. Capsule yield

Next to general vegetative growth of the whole plant the first noticeable effect of banded P fertiliser, and in particular the N1 P1 combination, was the effect on numbers of capsules per plant. The N x P interaction effect was expressed as a 50% greater number of capsules per plant at N1 P1 compared with N0 P1 and this effect strongly controlled capsule dry matter yields (Table 32).

The overall effect of the N1 P1 combination was to give a 13% increase in dry matter yield of total capsules compared with N0 P1 (Table 35). However this nett result was made up of a large N x P interaction effect from lateral capsules (Table 34) and a small but significant yield depressing effect of P application on terminal capsules (Table 33). Nitrogen also showed a trend (not significant) to depress the yield of terminal capsules.

The fact that the yield of terminal capsules was depressed by relatively high rates of P (100 kg/ha P) in this experiment may be a point of potential practical importance. The numbers of capsules per plant were increased by P application from 1.5 at N1 P0 to 2.2. at N1 P1 and this may involve two possibilities: (i) A re-distribution of plant nutrients and substrate within the plant which are then diverted to lateral capsules at the expense of terminal capsules. (ii) A specific depressing effect of high levels of N and P on terminal capsule yield. One possible implication of the latter hypothesis is that if poppies were drilled at a higher density than the 50 plants/m^2 used in this experiment total capsule yield depressions may result from the application of high rates of banded N P. Increasing the plant density to a point where there was a situation of only one capsule per plant could be considered as a possible way of enhancing the uniformity of seed dry matter content and hence seed maturity at the earlier times of harvest. It may be that this manoeuvre would accomplish this end but at the same time depress or at least minimise the capsule yield response to banded N P fertiliser.

No studies of the effect of factorial combinations of banded N P fertiliser at different plant densities have been carried out in Tasmania nor does such work appear to have been recorded in the literature. However in a plant density study with oil poppies on a krasnozem at the same location as this experiment, Frappell (Personal Communication) has shown that there was a slight tendency for total capsule yield to decline as plant density rose from 50 to 150 plants/m^2. In this study capsules were not divided into terminal and lateral components and N P fertilisers were banded only at moderate rates of 20 and 40 kg/ha respectively. However this trend may be a reflection of the tendency for terminal capsule yield to decline as plant density increases and this may be aggravated with increasing application of banded N and P towards the high rate of 100 kg/ha used in this experiment.

5.4.3. Seed yield

The effect of banded N P fertiliser on seed yield was more complicated and differed markedly from its effect on total capsules, stem + leaves and total plant. Whereas N x P interaction effects were shown at all times of harvest for the latter components the effect of these fertilisers on terminal seed yield varied at different harvests. As seen in Table 36 there were time of harvest x P and time of harvest x N interactions for terminal seed yield. And in these interactions both N and P progressively reduced the yield of seed from terminal capsules as the time of dry commercial harvest approached. However this trend for terminal seed yield to fall was masked by the effect of both N and P in increasing yield of seed from lateral capsules (Table 37).

The nett outcome of the differing effects of N and P fertiliser on terminal and lateral seed yields gave a total seed yield which was increased by P application at all times of harvest. But the effect of N was modified by a spray x N interaction in which N had a nil effect in the sprayed situation

but a significantly depressing effect in the non-sprayed situation. The implications of this effect will be discussed further in section 6 of this thesis.

The effect of higher rates of banded N and P fertiliser on the yield of seed from terminal capsules may also have important practical implications. The data of Frappell (Personal Communication) also showed that there was quite a marked tendency for total seed yield to decrease as plant density was increased. Therefore the argument that was used to predict decreases in terminal capsule yield under a high density cultural system with high rates of N P fertiliser may also apply *a fortiori* to the possibility of decreases in seed yield.

In addition to the possibility of high rates of banded N P causing yield reductions at very high densities, the converse may also apply. That is, the yield increases of capsule and seed achieved at the density of 50 plants/m^2 used in this experiment with N1 P1 combination were basically attributable to the effect on number of capsules/plant. It is therefore possible that still higher yields could be achieved at lower densities with similar high rates of N and P. If this latter relationship did apply to such an extent that the larger capsule numbers were diffused over a greater length of the plant then it may be disadvantageous for machine harvesting at the dry capsule stage. It may mean that excessive quantities of stem would need to be included to reap all the capsules. This speculation raises the further possibilities of breeding more suitably compact varieties or alternatively the possibility of harvesting the whole green plant or part of it as discussed in Section 4 of this thesis.

5.4.4. Nutrient imbalance

An alternative explanation of the decreases in yield of terminal capsules due to high rates of banded P (Table 33) and the decrease in seed from terminal capsules due to high rates of banded N (Table 36) may

be partially related to nutrient imbalance. Although soil potassium levels were relatively high in this experiment (83 m.e./10 kg of soil) K may have become a limiting factor at the high levels of 100 kg/ha for each of N and P. When potassium was applied at 75 kg/ha on the krasnozem it failed to give a response when broadcast in factorial combination with 15 kg/ha P similarly broadcast (Frappell, Personal Communication). However responses may still be obtained from K application at the higher levels of P used in this experiment

5.5. Conclusions

In this experiment N x P interaction effects were recorded for dry matter yield of total plant at all times of harvest after flowering (Table 40). Prior to flowering and when measured twelve weeks after sowing the N1 P1 treatment exceeded N0 P1 by 74% (Table 31). N x P interaction effects were also recorded for the components of lateral capsule yield, total capsule yield, total capsule number per plant and the yield of stem and leaves. For these characteristics N1 P1 exceeded N0 P1 by 57%, 13%, 30% and 18% respectively (Tables 34, 35, 32, 39).

Phosphorus fertiliser had a small but significantly depressing effect and nitrogen had a nil effect on terminal capsule yield (Table 33). However the yield of seed from terminal capsules was modified by a time of harvest x P and also by time of harvest x N interaction which resulted in yields being depressed at the later harvests (Table 36). Mean seed yield from lateral capsules was increased by both N and P at all times of harvest (Table 37).

6. THE EFFECT OF FUNGI ON YIELD OF MORPHINE

6.1. Introduction

In the fertiliser experiment described in section 2.4. the capsules were heavily infected with fungi and morphine levels were only about half the expected average. This type of variation has been experienced in the European poppy growing areas and some authors have attributed a significant part of the variation to fungal attack (Kopp 1957, Kleinschmidt and Mothes 1958, Miczulska 1967).

In the field fertiliser experiment at Forthside in 1970/71 (2.4.) many of the capsules with surface growth of fungi also appeared very susceptible to bird attack with obvious cracking of the capsule wall. This suggested that the fungi had actually penetrated and weakened the capsule wall and strengthened the suspicion that they may have been significantly involved in the low morphine concentration of capsules.

Samples of fungal-colonised capsules were taken from this field experiment for identification of the fungi involved. Microscopic sections of the capsule wall were also taken from capsules free of fungi and those with heavy fungal growth. In addition the fungal isolates were inoculated onto ground capsule material to assess whether they could break down morphine. This experiment and the identification of capsules are described in section 6.2.

In the 1971/72 season, although fungal colonisation of capsules was relatively low some associations were drawn between degree of fungal cover and capsule morphine content. These studies are set out in section 6.3.

In the field experiment of 1973/74 studying time of harvest and set out in detail in section 4.3., fungicidal sprays were also included. The object of this was as follows:-

(i) To assess the effect of fungicidal sprays on the dry matter and morphine yields of the various plant components when the whole plant was harvested at weekly intervals after full bloom.

Plate 12. An external view of a heavily infected capsule (left) with an uninfected capsule on the right.

(ii) To monitor the development of fungi on terminal capsules at each time of harvest.

The results of this study are set out in section 6.4.

6.2. The Effect of Fungi on the Morphine Concentration of Ground Capsule Material

6.2.1. Materials and Methods

6.2.1.1. Fungal identification

Capsules were examined from the field experiment at Forthside (section 2.4.). In all cases fungi were sporulating on capsules and readily identifiable. Isolates were maintained on slopes of potato dextrose agar. Isolations from seed were made by placing directly on PDA plates commercially captan-dusted seed, undusted seed from infected capsules and seed which was surface sterilised for one minute with 0.1% mercuric chloride.

Microscopic sections of fungal-colonised and non-colonised capsule wall are shown in plates 13 and 14 at a magnification of x 300.

6.2.1.2. Fungal inoculation of ground capsules

The ability of the three isolated fungi to utilise morphine was determined by growing them on a moist ground capsule medium and analysing this for morphine content. Whole capsules, not including seed, were ground in a mill to pass a one mm sieve. This material was divided into equivalent samples of four grams by repeated coning and quartering. Twenty nine samples of four grams each were placed in glass petri dishes. Each sample was mixed to a paste with 5 ml. of deionised water. Samples were autoclaved at 118°C for 20 minutes and morphine is stable at this temperature.

Inoculation with the three fungi was carried out by placing five pieces of 5mm square PDA with actively growing mycelium on each dish of autoclaved, cooled medium. There were six replicates of each fungus and controls of moist, uninoculated capsule material. These were incubated in a humid

atmosphere at 24°C for seventeen days, when one replicate was analysed to indicate the rate of morphine breakdown. The remaining plates were examined for the presence of contaminants and analysed on the twenty-fourth day.

Dry, uninoculated powder was retained for morphine analysis to indicate whether hydrolysis or general breakdown of morphine was occurring in the moist samples. In this experiment the six replicates were set out in a completely randomised design.

6.2.2. Results

6.2.2.1. Identification of fungi

The fungi occurring on the surfaces of capsules in this experiment were sent to the Commonwealth Mycological Institute at Kew in the United Kingdom. They were identified as follows:- Cladosporium macrocarpum Preuss, Cladosporium herbarum (Pers) Link ex S. F. Gray, Alternaria alternata (Fr.) Keissler, Stemphylium vesicarium (Wallr). Simmons, the conidial stage of Pleospora papaveracea (de Not) Sacc.

Only Alternaria sp. and Helminthosporium sp. (the imperfect stage of Pleospora papaveracea) were isolated from captan-dusted and surface sterilised seed.

6.2.2.2. Microscopic examination of capsule wall sections

A comparison of infected and non-infected capsule wall sections showed that the fungi had penetrated the interior of the wall and disrupted the cellular structure (Plates 13 and 14). The fact that seed was also infected implied that fungi had penetrated right into the interior of the capsules.

6.2.2.3. Morphine concentration of dry ground capsules inoculated with fungi

The morphine concentration of fungal inoculated and uninoculated capsule material is set out in Table 41. Alternaria and

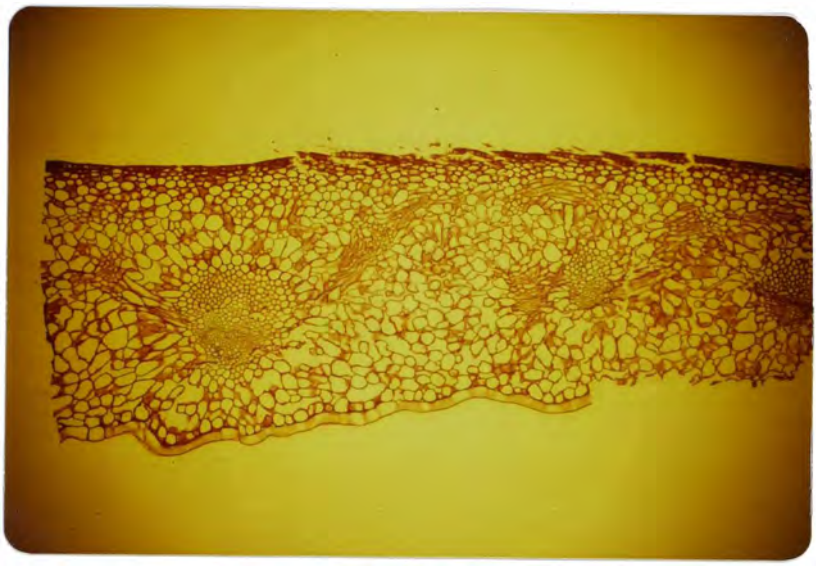


Plate 13. A transverse section of the wall from an uninfected capsule showing vascular bundles and related laticifers (see 1.4.). Stained with haematoxylin. (x250).

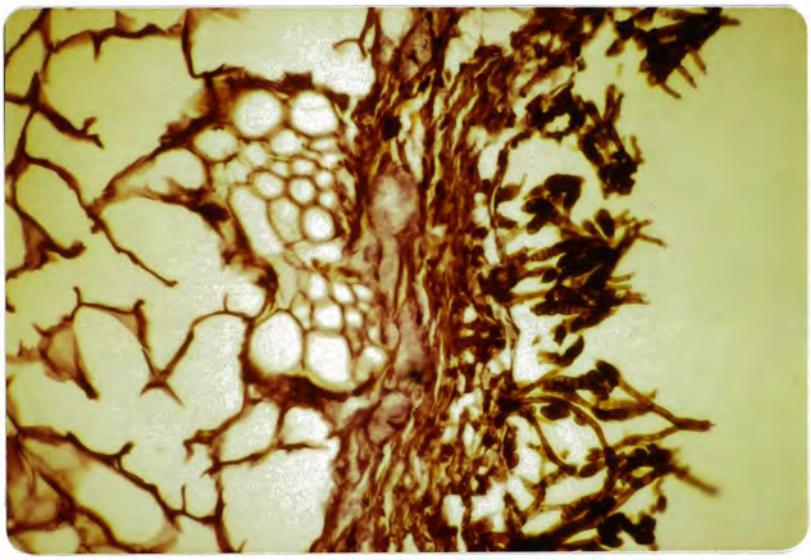


Plate 14. A transverse section of the wall from an infected capsule showing surface colonisation by fungi and penetration of hyphae into the interior with disruption of cells. Stained with haematoxylin. (x250).

Helminthosporium (Dendryphion) sp. depressed morphine concentrations to levels very significantly ($P < 0.01$) less than either the moist (autoclaved) or dry uninoculated treatments or Cladosporium (Table 41).

Table 41. The effect of fungi on the morphine concentration of dry ground capsules 24 days after inoculation

Treat. No.	Treatment	Morphine %	
		24 days	17 days*
1	Alternaria	0.15	0.23
2	Cladosporium	1.22	1.26
3	Helminthosporium	0.10	0.16
4	Moist uninoculated	1.25	1.31
5	Dry inoculated	1.40	1.40
L.S.D.	$P < 0.05$	0.042	
	$P < 0.01$	0.057	

* The morphine concentrations at 17 days after inoculation were obtained from a single replication.

6.2.2.4. Rate of growth of fungi

With the method of inoculation used for the fungi shown in Table 41 a time lapse was apparent between inoculation and complete coverage of the plant with mycelium. This time differed between fungi and the time taken for complete coverage by the respective fungi is set out below in Table 42.

Table 42. The time interval between initial fungal inoculation and complete coverage of Petri dish (Days)

Fungi	No. of Days
Alternaria	8
Helminthosporium	13
Cladosporium	Incomplete after 24 days

Plate 15. The hand spray apparatus with boom and protective baffles used to apply fungicides to the spray treated plots.

Plate 16. Petri dishes of ground capsule showing growth of (1) Helminthosporium, (2) Alternaria, (3) Cladosporium, (4) Moist control, (5) Dry control.

6.2.3. Discussion

It is quite clear from the data given in Table 41 that both the Alternaria sp and the Helminthosporium sp fungi drastically reduced capsule morphine to less that one tenth of the level in the dry, uninoculated controls. Also the isolation of Alternaria sp and Helminthosporium sp from the seed confirmed the visual evidence of the microscopic observation (Plate 14) that fungi do penetrate and disrupt the cellular structure and enter the interior of the capsule.

The fact that Cladosporium did not reduce morphine concentration significantly below that of the dry uninoculated control may be a reflection of the experimental method used. Cladosporium had a slow rate of lateral spread on the surface of the ground capsule and even after 24 days did not completely cover the surface. The high moisture level of the capsule medium may have inhibited its spread and thus limited the possibility of morphine breakdown. On this aspect Follstad (1966) reported that aeration was a vital factor in the growth of Cladosporium herbarum. In addition to this, Cladosporium was the dominant fungus colonizing the surface of capsules in the field trial at Forthside (section 2.4.) and one of the two reported by Miczulska (1967) as being associated with morphine losses in Polish experiments.

A point of some importance in this experiment was the fact that the moist, uninoculated control was significantly lower in morphine than the dry uninoculated capsule material (Table 41). This may imply some form of hydrolytic breakdown of morphine and can be compared with the observation of Kopp (1957) that harvested capsules stored in a moist atmosphere showed significant reduction in morphine content.

6.3. The Association between Fungal Colonisation and Morphine Concentration of Intact capsules.

6.3.1. Materials and Methods

The association between degree of infection and morphine

levels was studied in a 2 x 2 factorial at Forthside Vegetable Research Station. The plots were drilled 3rd October 1971 with N0 = Zero, and N1 = 200 kg/ha N as ammonium sulphate. Concentrated superphosphate was applied to give P0 = zero and P1 = 200 kg/ha P. All treatments had contact P applied with the seed to give 20 kg/ha P. A Tasmanian cultivar was drilled in 200 mm rows and the plot size was 8.5 metres long and 1.6 metres wide. The plots were laid out in a randomised block with four replications. At harvest on the 28th February 1972 the combined terminal and lateral capsules were divided into three sub-plot categories depending on the percentage of the total surface area which was colonised by fungi. The three categories were judged by eye as follows :- Slight = 0-10%, Medium = 11-30%, Severe = 30%.

6.3.2. Results

As there were no interactions between fertiliser treatment and infection categories the morphine concentrations of capsules are set out in Table 43 as the means of the four fertiliser treatment for each infection category.

Table 43. The effect of level of infection on the mean morphine content of intact capsules (%)

Infection Category		Morphine (%)
Slight		1.34
Medium		1.19
Severe		1.07
L.S.D.	P < 0.05	0.07
	P < 0.01	0.09

Table 44 records the percentage of the total number of capsules per plot which were in the severe infection category.

Table 44. The effect of fertilizer treatment on the proportion of total number of capsules per plot in the severe infection category (%)

	Po	P1	Mean
No	8.27	5.30	6.79
N1	12.88	21.55	17.21
Mean	10.57	13.42	

L.S.D. Within Table $P < 0.05 = 4.95$ $P < 0.01 = 7.12$

Marginal means $P < 0.05 = 3.51$ $P < 0.01 = 5.04$

6.3.3. Discussion

Table 43 shows that the higher the degree of fungal colonisation the lower the concentration of morphine in the capsules. There were significant differences ($P<0.01$) between each of the categories and the severe category had 20% lower morphine than the slight category. Table 44 shows that nitrogen was effective in increasing the percentage of capsule numbers in the severe category. There was also a significant N X P interaction whereby this effect of N was reinforced at high levels of P. The failure of N either to clearly increases capsule morphine or dry matter yield of capsule in the field trial of 1970/71 (Table 10 and 12) may have been associated with the above effect in that year.

6.4. The Effect of Fungicidal Sprays and Time of Harvest on Yield Components, Morphine Production and Fungal Colonisation

6.4.1. Materials and Methods

The full details of the method of carrying out the overall field experiment have been set out in section 4.3. However the essential details of the fungicidal spray treatments are repeated here together with the laboratory method of monitoring the development of fungi on terminal capsules at each time of harvest. In addition measurements were made of

the surface colonisation of both terminal and lateral capsules at harvests 10, 11 and 12 as visual control effects of spraying became apparent and the geographical orientation of the sporulating lesions was observed. These measurements consisted of the following:-

(i) The percentage of the total surface area which was covered by sporulating fungi was estimated. As gross differences were apparent, visual estimates were considered adequate, despite difficulties caused by the shape of the capsule and the patchy distribution of the fungi.

(ii) Because the region of the capsule which was superficially colonised by fungi appeared to have a particular geographical orientation this was defined by the following measurements:-

(a) The "angular range" or the angle encompassed between the margins of the colonised area.

(b) The "central focus" which was the geographical bearing of the line bisecting the angular range. The central focus was then used as a summarising figure defining the orientation of colonisation. The method by which the angular range and central focus were measured was to note the field plot row orientation by inscribing a small mark on each side of the capsule. In addition the general location of the colonised patch with respect to general north or south was also noted. The angular range and central focus were then located by the compass ring apparatus shown in Plates 17 and 18 and the results set out in Table 53. On this compass ring device, the orientation of the experimental rows of poppies is shown by a thick, broken line.

The fungicidal spray treatment consisted of 2 kg/ha Benomyl (50% a.i.) + 2 kg/ha (80% a.i.). The mixture with "Agral" wetting agent was sprayed on the whole plant at 10 day intervals commencing at flowering and continuing until the completion of the experiment approximately one month after dry harvest maturity. The plots were sprayed using a hand boom with protective baffles (Plate 15). This fungicide mixture was chosen to provide

as wide a cover a possible. Mancozeb being a broad spectrum contact fungicide and Benomyl a narrow spectrum systemic fungicide with known activity against Cladosporium.

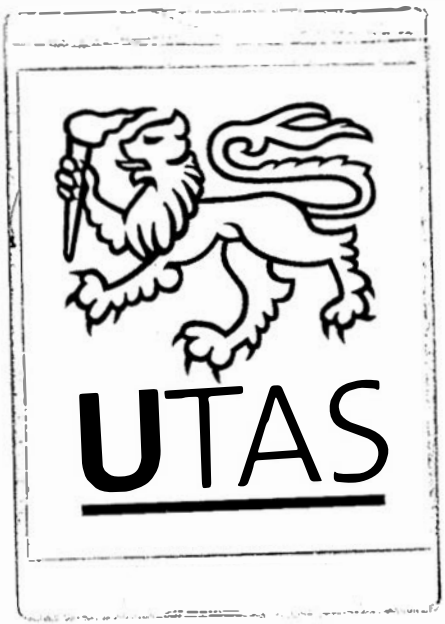
The effect of the fungicidal spray treatment on morphine concentration and morphine yield is based on the N1 P1 fertiliser treatment only. However the general effect of the spray treatment on dry matter yield is given for the four factorial combinations of N and P fertiliser.

6.4.2. Identification of capsule fungi

In the situation where fungi were invading green and later senescing capsule tissue, without forming discrete lesions it was not possible to monitor their development by rating size or number of superficial lesions. It was therefore necessary to culture capsule segments on agar to obtain an estimate of fungal invasion.

Commencing at harvest 2, ten plants were selected at random from the replicates of the N1 P1 sprayed and N1 P1 non-sprayed treatments and the terminal capsules removed. A random position was selected on one side of the capsules and another position 180° away on the other side and strips of capsule wall 2-3 mm wide were cut from the top near the stigmatic disc to the base of the capsule at these positions. Each of these strips of capsule wall was cut into five equal segments thus giving a total of 10 pieces per capsule and 100 pieces per sub-plot. The segments of capsule wall were sterilised for 60 seconds in 0.1% mercuric chloride and 0.1% Teepol. They were then washed twice with sterile water for two minutes each and plated onto water agar. Ten segments were used on each plate positioned around the perimeter of the dish. They were then incubated at 23°C and examined seven days later for the presence or absence of fungi on each segment. This procedure of harvesting the N1 P1 sprayed and N1 P1 non-sprayed treatments was carried out from harvest 2 to harvest 7. In addition, at commercial harvest 8, all fungi from these plots were subcultured and identified to genus level.

At harvests 8 and 12, plots of the full factorial range of fertiliser and spray treatments were sampled and examined for the presence or absence of fungal growth.



6.4.3. Results

6.4.3.1. Fungicidal spray effects on capsules

Dry Matter

The mean effect of the spray treatment (S) over all fertiliser and all times of harvest (T) was to give 7%, 19% and 11% greater yield of terminal, lateral and total capsules respectively (Table 45). There were no interactions with fertilisers as such but there were some interactions of T X S X fertiliser for the first two or three harvests. These were just significant and did not substantially modify the general effects of spray presented below, particularly in the periods of dry commercial maturity and two or three weeks before this.

Table 45. The mean effect of fungicidal sprays on dry matter yield of poppy capsules (kg/ha)

Capsule	Yield		l. s. d.	
Components	Sprayed	Non-Sprayed	P<0.05	P<0.01
Terminal (kg/ha)	973	906	32	43
Lateral (kg/ha)	386	324	42	57
Total Capsules (kg/ha)	1359	1230	54	73
Total Capsule no./m^2	92.86	87.43	3.61	4.91

Morphine concentration and yield

The morphine concentration and yield of capsules meaned over twelve times of harvest are set out in Table 46. Although there was a trend for the spray treatment to give a higher concentration and yield of morphine in both terminal and lateral capsules this difference was not significant. As noted in section 6.4.1. the observations on morphine concentration and yield were based on the N1 P1 fertiliser treatment only, whereas dry matter was measured over the four factorial combinations. In

this situation the 20% numerical difference in total capsule morphine yield could not be shown as significant.

Table 46. The mean effect of fungicidal sprays on morphine content (%) and morphine yield of poppy capsules (kg/ha)

	Morphine Concentration(%)		l.s.d.	Morphine Yield (kg/ha)		l.s.d.
Capsule	Sprayed	Non-Sprayed	P<0.05	Sprayed	Non-Sprayed	P<0.05
Terminal	0.88	0.83	NS	8.11	7.10	NS
Lateral	0.96	0.90	NS	5.70	4.39	NS
Total	0.90	0.84	NS	13.81	11.49	NS

6.4.3.2. Fungicidal spray effects on seed

In the case of both terminal and lateral capsules there is a trend (not significant) for the spray effect to vary depending on whether it is applied in the presence or absence of nitrogen fertiliser. This trend is compounded and expressed as a significant ($P < 0.05$) spray x N interaction for total seed yield. The implication of this spray x N interaction is that N may depress seed yield of the non-sprayed plants at all times of harvest (Table 47).

Table 47. The mean effect of fungicidal sprays on the dry matter yield of poppy seed (kg/ha).

Nitrogen	Terminal Seed		Lateral Seed		Total Seed	
	Sprayed	Non-Sprayed	Sprayed	Non-Sprayed	Sprayed	Non-Sprayed
N0	1421	1377	386	358	1808	1734
N1	1320	1191	517	378	1837	1568
Mean	1371	1284	452	368	1823	1657

l.s.d. spray means

$P < 0.05$ = 56 59

$P < 0.01$ = 76 80

l.s.d. within total seed table

$P < 0.05$ = 114

$P < 0.01$ = N.S.

6.4.3.3. Fungicidal spray effects on stem and leaves

Dry Matter Yield

The mean effect of the spray treatment on the dry matter of stem + leaves was to give a 13% greater yield and as there were no interactions with time of harvest this was the general order of difference at all times of harvest (Table 48).

Morphine Concentration

The morphine concentration of stem + leaves was affected by a spray x time of harvest interaction and this effect was mainly attributable to a large increase due to spray soon after flowering. However the interaction is also contributed to by a trend for a

number of the non-sprayed treatments to have slightly higher morphine levels than the sprayed treatments (Table 48).

Morphine Yield

Similarly to morphine concentration the morphine yield of stem and leaves was also affected by a spray x time of harvest interaction attributable to the same factors operating on morphine concentration.

Table 48. The effect of time of harvest and fungicides on dry matter yield, morphine concentration and morphine yield of stem and leaves.

Harvest Number	Days after full bloom	Dry matter (kg/ha) spray	non-spray	mean	Morphine conc.(%) spray	non-spray	mean	Mor. Yield(kg/ha) spray	non-spray	mean
1	10	9078	7762	8420	0.12	0.06	0.09	10.85	4.88	7.86
2	17	8629	9454	9042	0.06	0.05	0.06	5.35	4.88	4.91
3	24	10221	6659	8440	0.08	0.10	0.09	8.40	6.53	7.46
4	31	7046	7048	7227	0.07	0.08	0.08	5.20	5.78	5.49
5	38	7198	6278	6738	0.11	0.08	0.10	7.75	5.05	6.40
6	45	7397	6226	6832	0.07	0.09	0.08	4.70	5.45	5.06
7	52	6542	6395	6469	0.05	0.07	0.06	3.00	4.30	3.65
8	59	5788	5244	5516	0.04	0.05	0.04	2.08	2.33	2.20
9	66	6249	5483	5866	0.04	0.07	0.05	2.43	3.63	2.03
10	73	6792	4662	5727	0.04	0.03	0.03	2.48	1.58	2.03
11	80	5363	6205	5784	0.04	0.05	0.04	1.95	2.85	2.40
12	94	4593	3727	4160	0.06	0.05	0.06	2.60	1.85	2.30
Mean		7105	6265		0.06	0.06		4.75	4.05	

l.s.d. for means	spray	time	spray	time	spray	time
P < 0.05 =	552	1073	NS	0.02	NS	1.80
P < 0.01 =	751	1363	NS	0.03	NS	2.39

l.s.d. within Table 48 for comparing morphine concentrations and morphine yield of

P < 0.05 = 0.03 (morphine conc.) P < 0.05 = 2.55 (morphine yield)

P < 0.01 = 0.04 (morphine conc.) P < 0.01 = 3.38 (morphine yield)

sprayed and non-sprayed treatments either at any one time of harvest or at two different times of harvest.

6.4.3.4. Fungicidal spray effects on total plant .

Dry Matter Yield .

The spray treatment gave 14% greater mean dry matter yield than the non-sprayed treatment as might be predicted from the previous exposition of spray effects on the component parts of the poppy. And in the case of the total plants this mean effect was indicative of the situation at each time of harvest. Seed weight was included in total plant dry wt. (Table 49).

Morphine concentration .

The various compensating factors controlling morphine concentration in the poppy components had the netteffect of giving the same concentration in the total plant whether sprayed or non-sprayed. (Table 49).

Morphine yield .

The mean effect of the spray treatment was to give a trend towards a 20% greater yield of morphine and as there were no interactions with time of harvest this difference is indicative of the effect at each time of harvest. For the same reasons outlined for capsules this difference could not be shown to be significant (Tables46 and 49).

Table 49. The effect of time of harvest and fungicides on mean dry matter yield, morphine concentration and morphine yield of total plant

Treatment	Dry Matter (kg/ha)	Morphine Concentration (%)	Morphine Yield (kg/ha)
Sprayed	10576	0.18	18.56
Non-sprayed	9244	0.17	15.54
l.s.d. $P < 0.05$ =	749	N.S.	N.S.
$P < 0.01$ =	1020		

6.4.3.5. The fungal invasion of terminal capsules

Time effects

Table 50 may be taken as an index of the degree of fungal infection of the terminal capsules and it is clear that as early as harvest 2 the capsules were infected by a range of fungi which were identical with those enumerated in Table 52. After harvest 4 there was a noticeable trend for the degree of infection to increase and this may be compared with a sharp increase in the percentage dry matter of terminal capsules. A similar increase of infection occurred after harvest 7 (Table 50).

Spray effects

The application of the spray treatment appeared to be ineffective in controlling the growth of fungi at any time that the terminal capsules were examined between harvest 2 and harvest 8 (Table 50).

Table 50. The effect of fungicidal sprays and time of harvest on the percentage infection of terminal capsule segments.

Harvest Number	Days after Full Bloom	Percentage Infection			Percentage Dry Matter		
		Spray	Non-spray	Mean	Spray	Non-Spray	Mean
H2	17	46.7	44.5	45.6	16.9	16.4	16.7
H3	24	43.5	50.0	46.7	17.6	17.5	17.6
H4	31	44.0	42.5	43.2	18.7	18.3	18.5
H5	38	50.7	55.5	53.1	45.7	51.4	48.6
H6	45	52.2	51.7	52.0	83.2	81.5	82.4
H7	52	60.5	55.0	57.7	81.1	81.3	81.2
H8	59	73.7	78.4	76.1	85.4	84.3	84.9
H12	94	91.0	83.2	87.1	84.9	84.6	84.8
Mean		57.8	57.6				
l.s.d.	P< 0.05 =		N.S.	9.2			
	P< 0.01 =			12.4			

In addition to the sequential examination of terminal capsules from the N1 P1 treatment, examinations were also made of the full factorial range of fertiliser and spray treatments at harvest 8 (dry commercial harvest) and harvest 12. The data for the full factorial range set out in Table 51 shows that there was no significant differences between the fertiliser and spray treatment at either of these times of harvest.

Table 51. The effect of fungicidal sprays and fertiliser on the percentage infection of terminal capsule segments (Mean % of H8 and H12).

Treatment	P0	P1	Mean	N0	N1	Mean
Non-spray	81.3	77.8	79.6	78.6	80.5	79.6
Spray	76.8	82.4	79.6	79.3	79.9	79.6
Mean	79.0	80.0		79.0	80.2	
l.s.d.		N.S.	N.S.		N.S.	N.S.

6.4.3.6. Identification of fungal species

Capsules

From the first examination of terminal capsules at harvest 2, fungi of Helminthosporium, Alternaria and Stemphylium species were isolated. The large numbers which were isolated at each harvest prevented any close assessment of their relative contribution at each time of harvest. However at harvest 8 a number of isolates were sub-cultured from the N1 P1 treatment and later the genera were identified. The relative numbers of the isolates are set out in Table 52.

Table 52. The number and identification of fungi isolated and sub-cultured at harvest 8.

Genus	Numbers
Helminthosporium sp.	151
Alternaria sp.	177
Stemphylium sp.	25
Sterile mycelium with black pseudo sclerotes	171
Unidentified	24

Detailed examination of typical isolates of each group indicated that the species agreed with identifications which had been made previously by the Commonwealth Mycological Institute (sections 6.2.2.1.). These isolates from Tasmanian grown poppy capsules had been identified as the following: Helminthosporium papaveris (more correctly the Dendryphion state of Pleospora papaveracea), Alternaria alternata, Stemphylium vesicarium.

Although Cladosporium sp. was the most frequently sporulating fungus on the surface of capsules after harvest 9 it did not appear to be present in any of the cultures identified at harvest 8. The two species of Cladosporium which were identified as surface growths at harvests 9 and 11 were C. macrocarpum and C. herbarum.

Seed

Seeds from capsules taken at harvests 3, 4 and 5 were checked for the presence of fungi. None were detected at harvest 3 or 4 but at harvest five, 35% of capsules had some fungi which grew from unsterilised seed samples on water agar.

In addition, laboratory germination tests of air-dried seed taken at harvests 3 and 5 confirmed the finding that Helminthosporium infection was very common at harvest 5 but suggested that it also occurred at harvest 3. In these tests carried out at 20°C, symptoms of

Helminthosporium infection of the developing seedling occurred. When the germination tests were repeated on seeds collected at harvest 8 similar Helminthosporium symptoms were expressed at 20°C but not at 10°C or 15°C.

6.4.3.7. The orientation and severity of superficial fungal colonisation of capsules.

Orientation

About ten days after full bloom circular shaped, brownish black lesions up to 10 mm in diameter were observed on many capsules. These were not associated with any superficial fungi and it was noted that they generally appeared to be on the northern or western sides of capsules. These black lesions (Plate 19) appeared within two days following a very strong and persistent north westerly wind which had the indirect effect of removing a large quantity of the waxy bloom from the surface of the capsules. This was caused by the rubbing together of plants and in particular the abrasive effect of the serrated stigmatic disc at the top of the capsules (Plate 20).

At and after harvest 9 when growth of fungi was observed on the surface of capsules it was also noted that these appeared to have a distinct orientation. The true geographical bearing of this superficially colonised area and also its spread on the surface of the capsules are set out in Table 53 as the "focus" and "angular range" of colonisation. The focus of colonisation is approximately north north east and does not appear to be affected by either spray or fertiliser treatment. However the angular range of colonisation is less when the spray treatment is applied. This is consistent with the data of the percentage of surface area covered by fungi (Table 43).

Plate 17. The compass ring apparatus used to measure the "central focus" and "angular range" of fungal colonisation. The row orientation of field plots is represented by the thick black broken line and the capsule is placed in the centre of the ring as shown.

Plate 18. The opposite side of the capsule to that in Plate 17 almost completely free of superficial fungal colonisation, which was markedly localised on the northern side.

Table 53. The central focus and angular range of fungal colonisation on the surface of terminal poppy capsules at harvest 12.

Fertiliser treatment	Central focus (Geograph. bear.)		l.s.d.	Angular range (Degrees)		l.s.d.	
	Spray	Non-spray	P<0.05	Spray	Non-spray	P<0.05	P<0.01
N0 P0	34.3	27.8	N.S.	121	133	N.S.	N.S.
N1 P0	31.3	28.3	N.S.	109	126	"	"
N0 P1	25.0	22.8	N.S.	101	129	"	"
N1 P1	25.5	25.3	N.S.	103	126	"	"
Mean	29.0	26.1	N.S.	109	129	10	13

Severity

Apart from the lesions which were observed at harvest 1, superficial fungi as such did not appear until harvest 9 and the mean percentage of the surface area covered by these fungi at harvests 10 to 12 is set out in Table 49 for both terminal and lateral capsules. The spray treatment significantly ($P<0.01$) decreased the percentage fungal cover of both terminal and lateral capsules. Of the fertiliser treatments, phosphorus had a mean effect of increasing (P 0.01) the percentage cover of all capsules. Nitrogen had a tendency to decrease the cover of lateral capsules at all harvests, while the effect on terminal capsules varied with harvest. However the effect of phosphorus was more marked than nitrogen.

Plate 19. The type of dark lesions which appeared on the surface of capsules following strong winds soon after petal fall.

Plate 20. Part of the waxy bloom has been removedly by contact between capsules in windy weather. The serrated stigmatic disc at the top of capsules can easily scrape adjoining capsules.

Table 54. The effect of fungicidal sprays and nitrogen and phosphorus fertilisers on the superficial fungal cover of terminal and lateral capsules (Arcsin Percent)

Mean Treatment Effects	Terminal Capsules Arcsin Percent	%	Lateral Capsules Arcsin Percent	%
Fungicides				
Non-spray	16.24	7.8	11.93	4.3
Spray	5.21	0.8	3.99	0.5
l.s.d. P<0.05 =	1.44		1.49	
P<0.01 =	1.96		2.03	
Phosphorus				
P0	9.27	2.6	6.64	1.3
P1	12.18	4.5	9.28	2.6
l.s.d. P<0.05 =	1.44		1.49	
P<0.01 =	1.96		2.03	
Nitrogen				
N0	10.60	3.4	8.75	2.3
N1	10.86	3.5	7.17	1.5
l.s.d. P<0.05 =	N.S.		1.49	
P<0.01 =			2.04	

6.4.4. Discussion

6.4.4.1. Spray effects on dry matter accumulation and morphine yield

The application of the fungicidal spray treatment in this experiment had the effect of significantly increasing the dry matter yield of all plant components except seed. With respect to capsules, the spray treatment had its greatest impart on the yield of lateral capsules, giving an increase of 19%. Part of this yield effect is contributed to by

a small but significant increase in the number of lateral capsules but the bulk of the effect is on weight per capsule (Table 45).

Although the spray treatment had a similar effect on the morphine concentration and yield of capsules this could not be shown significant because of the limitations of the statistical design used.

The effect of the spray treatment on total seed yield in this experiment depended on the level of applied nitrogen fertiliser. Nitrogen had a depressing effect on the yield of seed from terminal capsules whether sprayed or not. And in contrast to this, nitrogen gave a large yield increase of seed from lateral capsules when sprayed but virtually no effect in the non-sprayed treatments. These opposing effects gave a spray x N interaction effect for total seed yields in which there was a nil effect of N when sprayed but a significantly depressing effect when not sprayed (Table 47).

The effect of the spray treatment on the morphine concentration and yields of the stem and leaf component was modified by a spray x time of harvest interaction (Table 48). This effect may have been contributed to by the fact that the stems of some plants were infected with Sclerotinia sclerotiorum. The trend for higher morphine concentrations in the stems and leaves of non-sprayed plants may have occurred because the fungus can cause constriction of the vascular system. This may have limited movement of latex and hence morphine from the stem to the capsules.

Similarly to the situation for capsule morphine the 20% numerical difference in the morphine yield could not be shown as a significant effect in this experiment.

6.4.4.2. Fungal invasion

The results of studies on fungi colonising capsules indicate that colonisation commenced early in the growth of the capsule and increased with capsule maturity and senescence. This colonisation of the green capsules occurred about one month earlier than any other observations

in Tasmania (Munro, Personal Communication) and as it coincided with the sudden appearance of lesions on capsules (Plate 19) it is likely that damage to tissue allowed this early entry. The damaged areas of capsules had an approximately northerly orientation and in this respect the damage was analogous to the type of localised high temperature injury which has been recorded for the circular flower heads (umbels) of onion seed crops (Tanner & Goltz 1972). However the severe and sustained wind battering experienced immediately prior to the appearance of the lesions and the concomitant stripping of the waxy bloom from the surface of capsules (Plate 20) also suggest themselves as likely contributors to capsule injury.

The fungi which were present in the capsule wall when the plant was green were not controlled by the application of the fungicidal spray so that it is unlikely that the observed increases in overall plant dry weight and morphine were connected with internal capsule fungal effects.

Although there was an effect of fungicides in decreasing the superficial cover of capsules by Cladosporium spp. these fungi only appeared after dry commercial harvest and their control would not explain earlier yield increases. Also these fungi frequently only colonise surfaces (e.g. sooty moulds) and this was confirmed by their absence from the surface of sterilised capsule segments. This they would probably have little effect on capsule or any other plant component dry weight or on morphine production. These superficial fungi would also be most likely to have a strong sink effect for plant metabolites which might explain the dry weight increases that occurred in stem and leaves when the fungi were controlled by spray application.

Therefore it appears unlikely that the dry weight and morphine increases which were associated with the fungicidal spray application were due to the control of fungi either in or on the capsules. There is no obvious alternative explanation for these yield increases but the following may be considered:

(1) Hormone (cytokinin) activity of Benomyl

(2) Control of fungi in plant components other than capsules e.g. (i) sclerotinia sclerotiorum and (ii) Helminthosporium papaveris.

The cytokinin activity of Benomyl has recently been demonstrated (Skene 1972) and caution in interpreting its effects has been recommended. The effects of cytokinins include increasing growth rate, increasing leaf area (Wensley 1972), retarding leaf senescence and reducing respiratory rates (Wittwer 1971). Although no yield increases have yet been attributed to the hormone activity of Benomyl this aspect has received little study and because of the frequent spray applications in this trial the possibility of an effect must be considered.

The non-target fungi which could have been controlled on components of the plant other than capsules are Sclerotinia sclerotiorum which was monitored in this experiment and Helminthosporium papaveris which was not monitored but appears to be very widespread in mature poppy crops in Tasmania.

The disease of lower stem and root induced by Helminthosporium papaveris has been observed to affect plants after flowering and all plants may be affected by time of commercial harvest (Munro, Personal Communication). Apart from its effect on seed yields (Mraz 1960, Ballarin 1950) the effects of Helminthosporium on other poppy plant components is not well documented. Grummer (1955) contends that the susceptibility of poppy leaves to infection is dependent upon a chlorosis with aging that is associated with chlorophyll reduction and in particularly protein degradation. Thus the retarded leaf senescence associated with the possible cytokinin effect of Benomyl may also have had an effect in reducing Helminthosporium infection in this experiment.

One must conclude that the reason that the dry weight and morphine yield increases following application is not clearly evident from this experiment but that both the cytokinin activity of Benomyl and the

control of the fungus Helminthosporium papaveris are possible explanations.

6.4.5. Conclusions

Both the laboratory experiment with ground capsules (Table 41) and the field association between degree of colonisation and morphine levels in intact dry capsules (Table 43) are strong evidence that fungi can deplete morphine. In addition the fungi isolated from capsules of low morphine content were the same or closely related to those involved with similar morphine losses in European poppy growing areas (Miczulska 1967).

When the colonization of capsules was studied between petal fall and dry maturity Helminthosporium sp. was isolated as early as seventeen days after full bloom (Table 50). There was also some evidence that this invasion of the capsule was related to physical damage and wind battering resulting in removal of the waxy "bloom" from the surface of capsules. Also at dry maturity there was notable orientation of colonization in which fungi were localised on the northern side of the capsule.

There were quite significant dry matter yield increases associated with the application of fungicidal sprays (Tables 45, 47, 48, 49) but the precise reasons for this were not clear. The effect may be partly related to control of plant fungi other than capsule fungi (section 6.4.4.2.) or possibly some hormone-like effect of Benomyl.

7. GENERAL DISCUSSION AND CONCLUSIONS

The high free ferric oxide content and high phosphorus fixation capacity of the krasnozem suggested that the separation distance between seed and fertilizer band could be important (Laughlin 1960, 1968). And the experiment in which the banded fertilizer was labelled with ^{32}P tended to confirm this hypothesis with respect to early uptake of banded P. There was greater uptake of banded P when it was placed 40 mm below the seed than when placed 75 mm below the seed. In addition maximum uptake of P occurred at an application rate equivalent to 100 kg/ha P for the 40 mm band compared with 200 kg/ha P for the 75 mm band. Dry matter yield of plants followed this uptake pattern closely. Although the field experiment on depth of banding showed a trend towards higher yields of capsule seed and morphine at dry maturity the differences were not significant (2.4.).

When nitrogen in the ammonium form was banded with phosphorus in two field experiments there were N X P interaction effects in terms of dry harvest yield of seed in both experiments and in terms of capsule and morphine yield in one. The general pattern of plant response which gave rise to these interactions was a lack of response to N application at zero or moderate rates of P and a marked effect at high levels of P. In one experiment (Table 3, 4, 6) P rates of 90 kg/ha were required and in the other (Table 9) 150 kg/ha before the yield effect was observed. The ratesof N required to produce this effect were 50 and 100 kg/ha N respectively. Thus a high concentration of both N and P appeared to be an essential feature of the harvest yield effect as was found for the early "N P" uptake effect from banded P (2.2.).

When the effect of banded N P fertilizer was measured at weekly intervals between flowering and dry maturity, N X P interactions were recorded for total plant yield at all times of harvest. When this total

yield was partitioned into the contributions from individual plant components, N X P interaction effects were found for lateral capsule yield, total capsule yield, total capsule number per plant and the yield of stem and leaves. For these characteristics the combination of banded N and P exceeded P alone by 57%, 13%, 30% and 18% respectively (Tables 32, 34, 35, 39).

The yield of terminal capsules was an exception to this pattern. Phosphorus fertilizer had a small but significantly depressing effect and nitrogen had no effect on this component (Table 33). One possible conclusion from this result is that if poppy crops were grown at high densities which produced only a single main stem capsule per plant then capsule yields may be depressed by high levels of P. Similarly the yield of seed from terminal capsules was modified by time of harvest X P and time of harvest X N interactions in which yields were depressed at the later harvests. In particular the depressions were maximal at the time of dry commercial harvest when the mean decrease due to P was 11% and that due to N was 17% (Table 36).

The application of lime in the form of calcium hydroxide had a marked and surprising effect, giving maximum yield of capsule, seed and stem and leaves at a rate equivalent to 25 t/ha and a bulk soil pH of 8.1 (Tables 16, 17, 19). In this experiment the banding of relatively high rates of N and P close below the seed probably gave a localised pH which was effectively lower than 8.1 and probably closer to the pH of 7 which the literature records as optimum for poppy growth. Although available soil phosphorus was increased by the application of $Ca(OH)_2$, plant analyses suggested that increased yields may have been more probably related to increases in magnesium, sodium, molybdenum or copper (Table 18).

These results tend to corroborate the general observations on the krasnozem that those areas where the pH increases with depth give higher yields than those in which the pH decreases with depth. On the krasnozem in Tasmania poppies are generally grown at pH values which range between 5.6 to 6.0 and below pH 5.6 very poor growth occurs. In their studies of the soils of the North West Region of Tasmania, Graley and Loveday (1961) observed that in some profiles pH increased with depth to values between 6.0 and 7.0 although generally they decreased with depth. It is on the areas where pH increased with depth that best commercial yields have often been obtained.

The very low morphine concentration in mature dry capsules from the field experiment at Forthside in 1970/71 (Table 11) prompted a detailed study of alternative methods of producing morphine in the Tasmanian environment. The sudden lowering of morphine content was a problem similar to that of the European industry (Kopp 1957, Bunting 1963, Miczulska 1967) and the lines of investigation followed were the possibility of losses due to (i) physical leaching and (ii) fungal breakdown. The results of section 3 of this thesis suggested that physical leaching could probably occur but that some form of chemical breakdown probably occurred within the wall of the capsule as well.

The fungal inoculations of dry, ground capsule material (Table 41) and the field association between level of fungal colonisation and morphine concentration in intact dry capsules (Table 43) was more conclusive evidence that fungi were involved in morphine losses. The main fungi identified were Helminthosporium (Dendryphion) papaveris, Alternaria alternata and Cladosporium herbarum and all of these fungi have been similarly implicated in morphine losses in Europe (Kopp 1957, Miczulska 1967).

Attempts to control capsule fungi by the application of a regular schedule of benomyl and mancozeb commencing at petal fall were not successful. Helminthosporium, Alternaria and Stemphylium species were all isolated from terminal capsule wall tissue in large numbers as early as seventeen days after full bloom and this level increased towards dry harvest maturity. The incidence was approximately the same in sprayed and non sprayed treatments (Table 5●).

The time of harvesting studies of Section 4. were undertaken to explore the possibility that the whole plant or some component could be harvested green and thus minimise the losses from the effects of fungi and leaching. These losses were thought to be greatest at the stage of dry harvest maturity. This study involved a preliminary survey of the pattern of morphine accumulation and decline in capsules between flowering and dry maturity (4.2.) and this pattern confirmed that found by Bunting (1963) in Southern England with maximum morphine levels occurring about two weeks before dry harvest. The pattern in the Tasmanian environment also followed that of Bunting (1963) and Schroder (1965) in that when rain and humid conditions occurred at and after dry maturity the capsule morphine levels fell quickly - a 30% decline - over a period of two weeks (Fig 2.).

The detailed investigations of the changes in morphine yield of capsules, stem and leaves, and total plant between flowering and dry maturity did reveal some possible alternatives to the current system of dry capsule harvest (4.2.). When the whole plant was harvested green at any time from two to six weeks after full bloom it produced 55% more morphine than dry capsules at the conventional time of dry harvest eight weeks after full bloom (Table 29). To achieve this yield the fresh weight of total plant material handled ranged from fifteen to five times that of dry capsules. The moisture content of the plant two weeks after full bloom was 80% and a month later it was 50% (Fig 3.).

The ratio of total plant morphine to capsule morphine at the time of dry commercial maturity was 1.55 : 1 in this experiment. Similar studies in East Germany have produced much greater advantages in favour of harvesting the green plant. Romisch (1953) obtained a ratio of 4 : 1 and Heeger and Schroder (1959) 2 : 1. However the maxima in these European studies tended to occur as a sharp peak about a month before dry harvest. In contrast the constant morphine yield from total plant in the Tasmanian experiment resulted from two mutually compensating factors. A gradual decline in dry matter yield of total plant from two weeks after full bloom which was offset by a gradual rise in morphine concentration up to six weeks after full bloom (Table 28). The economics of this alternative were not investigated in this study and would probably be of doubtful current commercial advantage. However the basic knowledge of the morphine derivable from the whole plant at an early stage could be of importance in some emergency situation of short supply.

Possibly the alternative of harvesting semi-ripe capsules about six weeks after full bloom may be a more viable economic alternative with respect to the cost of artificial drying. At that time in this study, capsules yielded 18% more morphine than from commercial dry capsule harvest two weeks later. One week after the time of commercial harvest the advantage was 43% in this study (Table 29).

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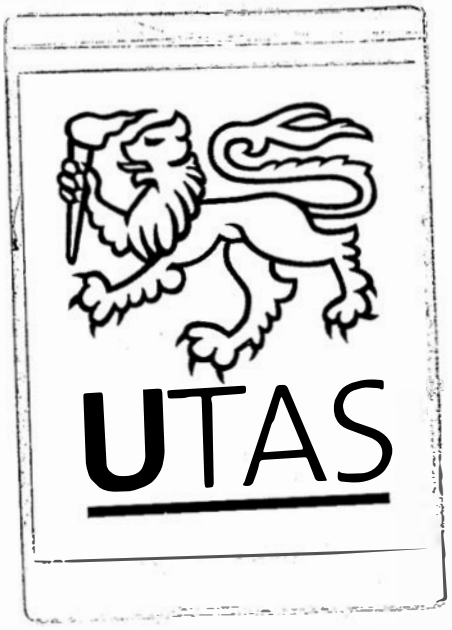

9. APPENDICES

(Raw Data and Analyses of Variance)

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APPENDIX 1.

NUTRITIONAL STUDIES WITH BANDED NITROGEN AND PHOSPHORUS FERTILISER

1.1. Effect of N P fertiliser and placement position on uptake of banded P and dry wt. per plant

1.1.1. The uptake of radioactive P (counts/sec/plant)

(Data on which Table 1 is based)

Treatments	Replication				
	1	2	3	4	5
Depth (D1)					
NO P1	32.187	41.953	54.473	57.825	50.685
NO P2	77.777	72.689	78.591	52.371	47.395
NO P3	59.390	49.527	65.645	46.159	59.854
N1 P1	37.113	52.581	64.504	61.891	34.511
N1 P2	31.543	108.380	51.636	36.651	62.274
N1 P3	68.801	83.004	67.765	90.155	72.692
N2 P1	28.030	57.278	37.774	34.472	45.753
N2 P2	28.360	70.311	50.795	70.487	42.689
N2 P3	37.974	47.941	68.180	47.106	54.635
N3 P1	17.084	23.845	13.572	21.308	39.998
N3 P2	44.208	100.985	30.244	62.516	44.237
N3 P3	29.509	30.978	35.267	51.071	33.301
Depth (D2)					
NO P1	108.240	32.468	21.029	34.860	37.919
NO P2	30.476	38.362	51.370	18.420	24.921
NO P3	23.450	46.095	76.087	35.308	44.908
N1 P1	37.858	20.338	32.091	24.973	21.935
N1 P2	45.986	18.539	36.352	16.259	18.162
N1 P3	31.253	28.790	49.517	55.878	64.405
N2 P1	23.852	34.382	75.033	19.376	Missing
N2 P2	19.485	33.336	57.464	23.037	48.726
N2 P3	34.225	10.292	38.904	56.509	64.619
N3 P1	15.168	20.405	22.392	16.652	Missing
N3 P2	20.754	31.929	5.305	15.979	51.319
N3 P3	39.965	41.636	36.231	51.296	48.219

1.1.1. Analysis of Covariance - radioactive P uptake (Counts/sec/plant).

Source of Variance	DF	Matrix of Corrected Sums of Squares and Products			Adjusted SS	MS	VR
P	2	4176.10			3231.79	1615.89	5.49**
		-7.79	.0167				
		-?.79	.0167	.0167			
N	3	4621.31			4109.35	1369.78	4.65**
		-0. 90	.0250				
		-9.75	-0.0083	.0250			
N x P	6	2408.81			2289.57	381.59	1.29
		1.35	.0500				
		-6.34	-0.0167	.0500			
D	1	8121.21			7066.11	7066.11	24.01**
		-8.22	.0083				
		-8.22	.0083	.0083			
P x D	2	1967.00			2327.13	1163.56	3.95*
		3.02	.0167				
		3.02	.0167	.0167			
N x D	3	1416.68			1698.54	566.18	1.92
		2.14	.0250				
		2.86	-0.0083	.0250			
N X P x D	6	1488.39			1331.86	221.97	.75
		-2.01	.0500				
		-1.78	-0.0167	.0500			
Error	94	29098.97			27655.59	294.20	
		-30.52	.8000				
		-14.92	.0000	.8000			
Total	117	53298.50					
		-42.93	.9917				
		-42.93	-0.0083	.9917			

1.1.2. Dry weight per plant (g)

(Data on which Table 2 is based)

Treatments			Replication				
N	P	D	1	2	3	4	5
1	1	1	.196	.217	.265	.288	.210
1	2	1	.358	.358	.360	.211	.236
1	3	1	.256	.230	.289	.212	.235
2	1	1	.157	.253	.258	.236	.152
2	2	1	.133	.414	.208	.138	.243
2	3	1	.270	.292	.239	.345	.285
3	1	1	.117	.215	.141	.129	.172
3	2	1	.114	.270	.165	.236	.156
3	3	1	.140	.169	.239	.173	.195
4	1	1	.063	.092	.047	.094	.158
4	2	1	.170	.351	.118	.213	.158
4	3	1	.105	.106	.116	.187	.114
1	1	2	.502	.146	.099	.182	.175
1	2	2	.152	.177	.216	.126	.121
1	3	2	.113	.216	.287	.154	.185
2	1	2	.176	.090	.157	.120	.082
2	2	2	.207	.089	.148	.068	.079
2	3	2	.142	.110	.200	.234	.240
3	1	2	.110	.129	.259	.093	.040
3	2	2	.079	.130	.210	.107	.185
3	3	2	.139	.042	.112	.208	.254
4	1	2	.071	.085	.093	.061	0
4	2	2	.100	.126	.044	.073	.191
4	3	2	.164	.137	.127	.186	.175

The raw data is taken from computer printout.
The lowest level of each variable is given as 1.
N = Nitrogen, P = Phosphorus, D = Depth of Application Below Seed.

1.1.2. Analysis of Variance - dry weight per plant (g)

Source of Var.	DF	SS	MS	VR
N	3	.172660	.057553	13.17
P	2	.030010	.015005	3.43
D	1	.104663	.104666	23.95
N X P	6	.038988	.006498	1.49
N X D	3	.023137	.007712	1.76
P X D	2	.024044	.012022	2.75
N X P X D	6	.020267	.003378	.77
Error	96	.419549	.004370	
Total	119	.833321		

1.2. Effect of Banded N P Fertiliser on Yields at Dry Harvest Maturity

1.2.1. Effect of banded N P and contact P on dry capsule yield (g/plot)

(Data on which Table 3 is based)

Treatment	Replication - No Contact "Super"		
	1	2	3
N0P0	240	310	310
N1P0	250	240	370
N2P0	290	270	320
N0P1	280	340	390
N0P2	270	320	360
N1P1	310	350	370
N1P2	310	360	420
N2P1	280	340	360
N2P2	370	420	520

Treatment	Replication - With Contact "Super"		
	1	2	3
N0P0	370	350	380
N1P0	440	250	280
N2P0	410	260	370
N0P1	400	270	470
N0P2	370	220	310
N1P1	460	360	320
N1P2	430	320	420
N2P1	430	320	380
N2P2	520	340	390

1.2.1. Analysis of Variance - dry capsule yield (g/plot)

Source of Var.		DF	SS	MS	VR
Replications		2	35744	17872.0	
Fertilizer (A)	N	2	11033	5516.5	3.679*
	P	2	27753	13866.5	9.248**
Predrilled	N X P	4	33100	8275.0	5.519**
Error (A)		16	23990	1499.4	
Fertilizer Contact (B)		1	14016	14016.0	0.377
Error (B)		2	74345	37172.5	
A X B	N X Contact P	2	145	72.5	0.056
	P X Contact P	2	8934	4467.0	3.460
	N X P X Contact P	4	3455	863.8	0.669
Error (C)		16	20655	1290.9	
Total		53	253150		

NOTE: * = 5% Probability

** = 1% Probability

1.2.2. Effect of banded N P and contact P on dry seed yield (g/plot)

(Data on which Table 4 is based)

Treatment	Replication - No Contact "Super"		
	1	2	3
N0P0	400	480	420
N1P0	390	380	570
N2P0	430	390	460
N0P1	420	540	690
N0P2	410	480	540
N1P1	500	580	610
N1P2	560	630	740
N2P1	450	530	510
N2P2	620	730	680

Treatment	Replication - With Contact "Super"		
	1	2	3
N0P0	660	560	640
N1P0	740	340	450
N2P0	720	390	560
N0P1	670	420	760
N0P2	510	290	530
N1P1	830	530	500
N1P2	780	520	770
N2P1	740	520	680
N2P2	940	520	710

1.2.2. Analysis of Variance - dry seed yield (g/plot)

Source of Var.		DF	SS	MS	VR
Replications		2	143077	71538.5	
	N	2	43911	21955.5	3.395
Fertilizer (A)	P	2	118533	59766.5	9.243**
Predrilled	N X P	4	16722	41905.5	6.481**
Error (A)		16	103457	6466.1	
Fertilizer Contact (B)		1	84807	84807.0	0.630
Error (B)		2	269360	134680.0	
	N X Contact P	2	6637	3318.5	0.919
A X B	P X Contact P	2	26548	13274.0	3.676*
	N X P X Contact P	4	19075	4768.8	1.321
Error 'C)		16	57773	3610.8	
Total		53	1040800		

2.2. Analysis of Variance - dry seed yield (g/plot)

(Component Analysis)

Source of Var.		Components	SS=MS	VR
	N	N Linear	37377.78	5.78*
		N Quadratic	6533.33	1.01
	P	P Linear	08900.00	16.84**
Predrilled (A)		P Quadratic	9633.33	1.49
Fertilizer		N Linear x P Linear	13437.50	17.54**
	N X P	N Linear x P. Quadratic	26068.06	4.03
		N Quadratic x P Lin.	27612.50	4.27
		N Quadratic x P Quad.	504.17	0.08

12.3. Effect of banded N P and contact P on capsule morphine content (%)

(Data on which Table 5 is based)

Treatment	Replication – No Contact "Super"		
	1	2	3
N0P0	1.08	1.12	1.14
N1P0	1.08	1.20	1.03
N2P0	1.15	1.09	1.11
N1P1	0.91	1.01	0.93
N1P2	0.89	0.99	0.93
N1P1	1.09	1.04	1.01
N1P2	0.98	1.14	1.01
N2P1	1.00	1.12	1.05
N2P2	1.09	1.09	1.16

Treatment	Replication – With Contact "Super"		
	1	2	3
N0P0	1.10	1.00	1.01
N1P0	1.04	1.03	0.99
N2P0	1.13	1.03	1.06
N0P1	1.04	0.87	1.01
N0P2	0.94	1.06	1.09
N1P1	1.12	1.06	1.05
N1P2	1.09	1.13	1.14
N2P1	1.02	1.04	1.11
N2P2	1.17	1.06	1.18

4.2.3. Analysis of Variance - capsule morphine content (%)

Source of Var.		DF	SS	MS	VR
Replication		2	0.00071	0.00036	
	N	2	0.07016	0.03508	8.57702**
Fertiliser (A)	P	2	0.02456	0.01228	3.00245
Predrilled	N X P	4	0.03455	0.00864	2.11247
Error (A)		16	0.06539	0.00409	
Fertiliser Contact (B)		1	0.00031	0.00031	0.02314
Error (B)		2	0.02679	0.01340	
	N X Contact P	2	0.00096	0.00048	0.31373
A X B	P X Contact P	2	0.04047	0.02024	3.22876**
	N X P X Contact P	4	0.00518	0.00130	0.84967
Error (C)		16	0.02444	0.00153	
Total		53	0.29352		

A.2.4. Effect of banded N P and contact P on capsule morphine yield (g/plot)

(Data on which Table 6 is based)

Treatment	Replication - No Contact "Super"		
	1	2	3
N0P0	2.59	3.47	3.53
N1P0	2.70	2.88	3.81
N2P0	3.34	2.94	3.55
N0P1	2.55	3.43	3.63
N0P2	2.40	3.17	3.35
N1P1	3.38	3.64	3.74
N1P2	3.04	4.10	4.24
N2P1	2.00	3.81	3.78
N2P2	4.03	4.58	6.03

Treatment	Replication - With Contact "Super"		
	1	2	3
N0P0	4.07	3.50	3.84
N1P0	4.58	2.58	2.77
N2P0	4.63	2.68	3.92
N0P1	4.16	2.35	4.75
N0P2	3.48	2.33	3.38
N1P1	5.15	3.82	3.36
N1P2	4.69	3.62	4.79
N2P1	4.39	3.33	4.22
N2P2	6.08	3.60	4.60

4.2.4. Analysis of Variance - capsule morphine yield (g/plot)

Source of Var.		DF	SS	MS	VR
Replications		2	3.754	1.377	
Fertiliser (A)	P	2	2.884	1.442	5.400
	N	2	3.741	1.371	5.134
Predrilled	N X P	4	6.854	1.713	6.415
Error (A)		16	4.273	0.267	
Fertiliser Contact (B)		1	2.224	2.224	0.384
Error (B)		2	11.595	5.798	
	N X Contact P	2	0.003	0.002	0.011
A X B	P X Contact P	2	0.430	0.215	1.214
	N X P X Contact P	4	0.551	0.138	0.779
Error (b)		16	2.843	0.177	
Total		53	39.151		

1.3. Effect of Banded N P Fertiliser and Depth of Banding on Yields at Dry Harvest Maturity

Key to Fertilizer Treatments in Tabulated daw Data

Treatment Symbol	Banded Treatment	Contact Treatment	Depth of Banding
A	N0P1		D1
B	N0P2		D1
C	N0P3		D1
D	N1P1		D1
E	N1P2		D1
F	N1P3		D1
G	N2P1		D1
H	N2P2		D1
J	N2P3		D1
K	N0P1		D2
L	N0P2		D2
M	N0P3		D2
N	N1P1		D2
P	N1P2		D2
Q	N1P3		D2
R	N2P1		D2
S	N2P2		D2
T	N2P3		D2
V	N1P2	L	D2
W	N1P2	P	D2
X	N1P2	L + P	D2
Y	N1P2		D2
Z	N2P3		D3

In treatment Y the form of N is Ammonium Sulphate and the form of P is Superphosphate (10%P). Yields and analyses are in g/m^2 but are converted in the text to kg/ha. There was no zero level of P in this experiment.

1. 3. 1. Effect of banded N P fertiliser and depth of banding on seed yield (g/m^2)

(Date on which Table 9 is based)

Treatment	Replication		
	1	2	3
A	226	203	238
B	239	354	245
C	244	260	247
D	218	208	340
E	243	260	225
F	234	291	242
G	206	229	243
H	240	228	285
J	256	310	410
K	232	264	224
L	258	233	328
M	252	288	262
N	190	214	327
P	207	237	281
Q	250	229	257
R	206	202	227
S	198	210	294
T	225	251	371
V	216	211	245
W	235	270	241
X	233	265	310
Y	265	222	208
Z	228	301	273

1.3.1. Analysis of Variance - seed yield (g/m^2)

Source	DF	SS	MS	VR
Block	2	22856.43	11428.21	8.2
Treatments	22	40348.31	1834.01	1.3
P Contact	1	2054.08	2054.08	1.5
L Contact	1	6.75	6.75	.0
P X L Contact	1	1102.08	1102.08	.8
P Banded	2	12947.11	6473.55	4.63
P Banded Linear	1	12920.11		9.24**
P Banded Quadratic	1	27.00		.01
N Banded	2	737.33	368.66	2.64
N Banded Linear	1	1.00		.00
N Banded Quadratic	1	736.33		.52
NP Banded	4	16576.88	4144.22	2.96
D	1	793.50	793.50	.56
DP	2	197.33	98.66	.07
DN	2	2635.11	1317.55	.94
DNP	4	1216.88	304.22	.21
Error	44	61480.89	1397.29	
Total	68	124685.65		

Degrees of Freedom (D.F.) do not add up to total due to common plots in the L X P and N X P factorials

1.3.2. Effect of banded N P fertiliser and depth of banding on capsule yield (g/m^2)

(Date on which Table 10 is based)

Treatment	Replication		
	1	2	3
A	100	98	110
B	109	167	114
C	115	123	114
D	110	108	167
E	121	125	108
F	113	149	121
G	116	120	126
H	123	124	141
J	132	156	187
K	113	127	107
L	115	103	148
M	112	123	117
N	93	101	160
P	98	117	139
Q	117	112	129
R	110	107	119
S	99	110	145
T	113	128	181
V	107	105	125
W	116	136	122
X	117	137	151
Y	130	114	100
Z	115	156	137

1. 3.2. Analysis of Variance - capsule yield (g/m^2)

Source	DF	SS	MS	VR
Block	2	4890.78	2445.39	8.1
Treatment	22	8907.27	404.87	1.3
P Contact	1	645.33	645.33	2.1
L Contact	1	16.33	16.33	.1
P X L Contact	1	192.00	192.00	.6
P Banded	2	1740.59	870.29	2.87
P Banded Linear	1	1736.11		5.72*
P Banded Quadratic	1	4.48		0.01
N Banded	2	1422.48	711.24	2.35
N Banded Linear	1	1369.00		4.51*
N Banded Quadratic	1	53.48		.17
NP Banded	4	2866.18	716.54	2.36
D	1	439.18	439.18	1.45
DP	2	103.70	51.85	.17
DN	2	456.92	228.46	.75
DNP	4	387.51	96.87	.32
Error	44	13344.55	303.28	
TOTAL	68	27142.60		

Degrees of Freedom (D.F.) do not add up to toal due to common plots in the L X P and N X P facotrials

1.3.3. Effect of banded N P fertiliser and depth of banding on capsule morphine concentration (%)

(Date on which Table 11 is based)

Treatments	Replication		
	1	2	3
A	0.59	0.53	0.56
B	0.62	0.64	0.62
C	0.59	0.58	0.61
D	0.58	0.58	0.70
E	0.59	0.66	0.53
F	0.62	0.64	0.56
G	0.64	0.63	0.62
H	0.56	0.60	0.67
J	0.52	0.61	0.72
K	0.59	0.61	0.57
L	0.61	0.56	0.62
M	0.59	0.64	0.61
N	0.53	0.60	0.61
P	0.51	0.59	0.59
Q	0.55	0.47	0.52
R	0.58	0.67	0.59
S	0.63	0.51	0.61
T	0.63	0.69	0.56
V	0.50	0.56	0.62
W	0.57	0.53	0.54
X	0.58	0.63	0.64
Y	0.60	0.54	0.57
Z	0.57	0.60	0.55

1.3.3. Analysis of Variance - capsule morphine concentration (%)

(Oil Poppies - Forthside)

Source	DF	SS	MS	VR
Block	2	.004	.0022	1.0
Treatment	22	.058	.0027	1.2
P Contact	1	.001	.0012	.5
L Contact	1	.003	.0033	1.5
P X L Contact	1	.004	.0040	1.8
P Banded	2	.0001	.000080	.03
N Banded	2	.0103	.00516	2.35
N X P Banded	4	.0115	.00289	1.31
D	1	.0052	.0052	2.36
DP	2	.0009	.0004	.20
DN	2	.0088	.0044	2.02
DNP	4	.0067	.0016	.76
Error	44	.0963	.0022	
Total	68	.1533		

Degrees of Freedom (D.F.) do not add up to total due to common plots in the L X P and N X P factorials

N.3.4. Effect of banded N P fertiliser and depth of banding on capsule morphine yield (g/m^2)

(Data on which Table 12 is based)

Treatment	Replication		
	1	2	3
A	0.590	0.519	0.616
B	0.676	1.069	0.707
C	0.679	0.713	0.696
D	0.638	0.627	1.169
E	0.714	0.825	0.573
F	0.701	0.954	0.678
G	0.742	0.756	0.782
H	0.689	0.744	0.945
J	0.686	0.952	1.347
K	0.667	0.775	0.610
L	0.702	0.577	0.918
M	0.661	0.787	0.714
N	0.493	0.606	1.008
P	0.500	0.690	0.821
Q	0.644	0.527	0.671
R	0.638	0.717	0.703
S	0.624	0.561	0.885
T	0.712	0.883	1.014
V	0.535	0.588	0.775
W	0.661	0.721	0.659
X	0.679	0.864	0.967
Y	0.780	0.616	0.530
Z	0.656	0.936	0.754

1.3.4. Analysis of Variance - capsule morphine yield (g/m^2)

Source	DF	SS	MS	VR
Blocks	2	.26	.1319	6.3
Treatment	22	.58	.0264	1.3
P Contact	1	.03	.0343	1.6
L Contact	1	.01	.0106	.5
P X L Contact	1	.02	.0282	1.4
P Banded	2	.052	.0260	1.253
P Linear	1	.052	.052	2.481
P Quadratic	1	.001	.001	.025
N Banded	2	.098	.0491	2.361
N Linear	1	.081	.081	3.878
N Quadratic	1	.018	.018	.845
NP Banded	4	.189	.047	2.283
N Quadratic X P Linear	1	.084	.084	4.044
D	1	.052	.0522	2.510
DP	2	.009	.0049	.240
DN	2	.041	.0207	.998
DNP	4	.033191	.0082	.399
Error	44	.7634	.0208	
Total	68			

Degrees of Freedom (D.F.) do not add up, due to common plots in the L X P and N X P factorials

1.3.5. Effect of banded N P fertiliser and depth of banding on capsule to head percentage (%)

(Data on which Table 13 is based)

Treatment	Replication		
	1	2	3
A	31	33	32
B	31	32	32
C	32	32	32
D	34	34	33
E	33	32	32
F	33	34	33
G	36	34	34
H	34	35	33
J	34	33	31
K	33	32	32
L	31	31	30
M	31	30	31
N	33	32	33
P	32	33	33
Q	32	33	33
R	35	35	34
S	33	34	33
T	33	34	33
V	33	33	34
W	33	33	34
X	33	34	33
Y	33	34	32
Z	34	34	33

1.3.5. Analysis of Variance - capsule to head percentage (%)

Source	DF	SS	MS	VR
Block	2	2.69	1.34	2.7
Treatment	22	71.15	3.23	6.5
P	1	.33	.33	.7
L	1	.33	.33	.7
P X L	1	.33	.33	.7
P	2	9.48	4.74	9.49
N	2	45.03	22.51	45.100
NP	4	3.85	.96	1.86
D	1	1.85	1.85	3.708
DP	2	.1481	.0740	.14
DN	2	1.03	.51	1.00
DNP	4	4.96	1.24	2.48
Error	44	21.97	.49	
TOTAL	68	95.82		

Degrees of Freedom (D.F.) do not add up to total due to common plots in the L X P and N X P factorials

1.4. Effect of Lime Application on Plant Survival, Yields and Plant and Soil Nutrient Status

1.4.1. Effect of Ca(OH)2 on plant survival (No. pot)

(Data on which Table 16 is based)

Ca(OH)2	Replication					
	1	2	3	4	5	6
Broadcast (t/ha)						
Zero - NP	12.00	12.00	14.00	12.00	14.00	11.00
Zero + NP	12.00	9.00	10.00	14.00	10.00	12.00
2.5	13.00	12.00	11.00	12.00	14.00	10.00
5	12.00	13.00	15.00	13.00	12.00	12.00
10	13.00	13.00	15.00	15.00	15.00	11.00
15	14.00	13.00	13.00	15.00	15.00	13.00
20	15.00	13.00	15.00	15.00	14.00	14.00
25	10.00	15.00	12.00	15.00	13.00	8.00
50	9.00	13.00	2.00	3.00	7.00	4.00
Contact (kg/ha)						
100	10.00	11.00	12.00	11.00	9.00	8.00
200	9.00	10.00	12.00	13.00	12.00	11.00
400	5.00	8.00	6.00	10.00	6.00	12.00
600	7.00	5.00	5.00	13.00	8.00	13.00
800	3.00	9.00	0.00	5.00	1.00	1.00
1000	4.00	5.00	2.00	1.00	8.00	0.00

1.4.1. Analysis of Variance - plant survival (No/pot)

Source of Var.	DF	SS	MS	F
Blocks	5	33.79	6.76	1.4
$Ca(OH)_2$	14	1205.29	86.09	18.1
Error	70	333.38	4.76	
Total	89	1572.46		

1.4.2. Effect of Ca(OH)2 on numbers of capsules (No./pot)

(Date on which Table 16 is based)

Ca(OH)2	Replication					
	1	2	3	4	5	6
Broadcast (kg/ha)						
Zero + N P	2.00	2.00	2.00	2.00	2.00	1.00
2.5	2.00	2.00	2.00	2.00	2.00	2.00
5	2.00	2.00	2.00	2.00	2.00	2.00
10	2.00	2.00	2.00	2.00	2.00	2.00
15	2.00	2.00	2.00	2.00	2.00	2.00
20	2.00	2.00	3.00	2.00	2.00	2.00
25	3.00	3.00	3.00	3.00	3.00	3.00
Contact (kg/ha)						
100	2.00	2.00	2.00	2.00	2.00	2.00
200	2.00	2.00	2.00	2.00	2.00	2.00
400	2.00	2.00	2.00	2.00	2.00	2.00
600	2.00	2.00	2.00	2.00	2.00	2.00

M.4.2. Analysis of Variance - capsule numbers (No./pot)

Source of Var.	DF	SS	MS	F
Blocks	5	0.18	0.04	1.2
$Ca(OH)_2$	10	5.79	0.58	19.5
Error	50	1.48	0.03	
Total	65	7.45		

1.4.3. Effect of Ca(OH)2 on yield of dry capsules (g/pot)

(Data on which Table 16 is based)

Ca(OH)2	Replication					
	1	2	3	4	5	6
Broadcast (t/ha)						
Zero + N P	.38	.65	.71	.54	.23	.38
2.5	1.85	1.32	1.20	1.04	1.34	1.47
5	1.65	1.83	1.63	1.18	1.57	1.05
10	2.28	1.49	1.47	1.88	1.97	1.71
15	3.92	2.97	3.08	2.76	3.24	2.54
20	2.87	4.45	4.17	2.96	2.89	2.36
25	4.62	5.78	5.04	3.79	4.41	4.23
Contact (kg/ha)						
100	1.85	.99	.75	.80	.68	.95
200	1.10	.71	.90	.87	.71	.65
400	1.00	1.22	.86	1.08	1.18	.66
600	1.02	1.23	1.14	1.24	1.05	1.17

1.4.3. Analysis of Variance - capsule yield (g/pot)

Source of Var	DF	SS	MS	F
Blocks	5	.51	.10	2.5
$Ca(OH)_2$	10	28.78	2.88	70.2
Error	50	2.05	.04	
Total	65	31.35		

4.4.4. Effect of Ca(OH)2 on yield of dry seed (g/pot)

(Data on which Table 16 is based)

Ca(OH)2	Replication					
	1	2	3	4	5	6
Broadcast (t/ha)						
Zero + N P	0.50	0.98	1.38	0.99	0.48	0.66
2.5	2.43	2.22	2.06	1.47	2.16	2.13
5	2.67	2.11	2.23	2.16	2.47	2.18
10	2.55	2.25	2.97	3.68	3.12	3.36
15	2.85	3.97	2.55	4.69	4.45	4.80
20	4.82	2.77	3.52	4.77	4.65	4.03
25	6.16	4.23	3.62	4.78	5.01	6.79
Contact (kg/ha)						
100	1.25	1.69	1.22	1.53	0.65	1.23
200	1.99	0.91	1.57	1.22	0.91	1.04
400	1.66	1.81	1.29	1.77	1.26	1.32
600	1.62	1.39	1.41	1.72	1.59	1.44

1.4.4. Analysis of Variance

Source of Var	DF	SS	MS	F
Blocks	5	0.23	0.05	0.7
$Ca(OH)_2$	10	20.67	2.07	32.9
Error	50	3.14	0.06	
Total	65	24.03		

1.4.5. Effect of Ca(OH)2 on soil pH

(Data on which Table 17 is based)

Ca(OH)2	Replication					
	1	2	3	4	5	6
Broadcast (t/ha)						
Zero + NP	5.4	5.3	5.2	5.3	5.3	5.3
2.5	5.7	5.9	5.7	6.1	6.0	5.9
5	6.4	6.4	6.2	6.1	6.4	6.5
10	7.1	6.9	6.9	7.3	6.8	7.1
15	7.8	7.9	7.7	7.9	7.8	8.0
20	8.0	8.0	7.9	8.0	8.0	8.0
25	8.1	8.1	8.0	8.1	8.1	8.1
50	8.3	8.2	8.1	8.2	8.0	8.3

1.4.5. Analysis of Variance (Soil pH)

Source of Var.	DF	SS	MS	F
Blocks	5	0.13	0.04	4.0
$Ca(OH)_2$	7	52.77	7.54	754.0
Error	35	0.39	0.01	
Total	47	53.34		

1.4.6. Effect of $Ca(OH)_2$ on available soil phosphorus (ppm)

(Data on which Table 17 is based)

$Ca(OH)_2$	Replication					
	1	2	3	4	5	6
Broadcast (t/ha)						
Zero - N P	35	34	38	39	39	40
Zero + N P	35	34	41	39	40	40
2.5	31	33	34	38	35	61
5	33	35	36	36	37	41
10	37	38	39	45	42	41
15	51	54	54	59	56	53
20	56	56	56	52	57	57
25	67	58	59	64	60	58
50	75	77	81	65	79	79

1.4.6. Analysis of Variance - soil phosphorus (ppm)

Source of Var	DF	SS	MS	F
Blocks	5	205.3	41.1	1.94
$Ca(OH)_2$	8	9139.8	1142.5	53.89
Error	40	846.4	21.2	
Total	53	10191.5		

1.4.7. Effect of Ca(OH)2 on available soil potassium (m.e./10 kg)

(Data on which Table 17 is based)

Ca(CH)2	Replication					
	1	2	3	4	5	6
Broadcast (t/ha)						
Zero - N P	36	37	34	32	34	36
Zero + N P	34	31	23	30	31	30
2.5	16	16	19	17	18	16
5	18	18	16	18	18	16
10	16	16	16	14	18	13
15	13	12	13	16	12	12
20	13	12	18	14	12	12
25	15	12	14	13	11	12
50	13	15	18	16	12	18

1.4.7. Analysis of Variance - Soil potassium (m.e./10 kg)

Source of Var	DF	SS	MS	F
Blocks	5	6	1.20	0.25
Ca(OH)2	8	3026	378.30	79.98
Error	40	189	4.73	
Total	53			

1.4.8. Effect of Ca (OH)2 on phosphorus content of stem and leaves (%)

(Data on which Table 18 is based)

Ca(OH)2 (t/ha)	Replication			
	1	2	3	4
0	0.04	0.09	0.23	0.06
2.5	0.09	0.11	0.09	0.08
5	0.07	0.10	0.10	0.075
10	0.14	0.075	0.13	0.055
15	0.08	0.08	0.07	0.06
20	0.07	0.06	0.055	0.07
25	0.045	0.055	0.11	0.055
50	0.02	0.09	0.05	0.07

1.4.8. Analysis of Variance (%P)

Source of Var.	DF	SS	MS	VR
Blocks	3	0.007084	0.002361	1.915
$Ca(OH)_2$	7	0.008847	0.001264	1.025
Error	21	0.025891	0.001233	
Total	31	0.041822		

1.4.9. Effect of Ca (OH)2 on potassium content of stem and leaves (%)

(Data on which Table 18 is based)

Ca(OH)2 (t/ha)	Replication			
	1	2	3	4
0	1.1	2.7	1.0	1.5
2.5	2.0	2.5	1.9	1.7
5	1.8	1.8	1.8	1.9
10	1.3	1.3	0.7	1.2
15	1.0	1.0	0.9	0.9
20	1.1	0.9	0.9	0.8
25	1.1	0.8	0.6	0.9
50	1.1	1.0	1.0	1.4

1.4.9. Analysis of Variance (% K)

Source of Var.	DF	SS	MS	VR
Blocks	3	0.64250	0.21417	2.160
$Ca(OH)_2$	7	5.61500	0.80214	8.089 **
Error	21	2.08250	0.09917	
Total	31	8.34000		

4.4.10. Effect of Ca(OH)2 on calcium content of stem and leaves (%)

(Data on which Table 18 is based)

Ca(OH)2 (t/ha)	Replication			
	1	2	3	4
2.5	2.17	1.72	1.40	1.75
5	1.50	1.45	1.40	1.25
10	1.72	1.53	2.12	2.10
15	1.50	1.95	1.72	1.67
20	2.00	1.81	1.25	2.00
25	1.85	2.80	1.90	1.55
50	1.60	1.60	1.23	1.32

4.4.10. Analysis of Variance (% Ca)

Source of Var.	DF	SS	MS	VR
Blocks	3	0.3707	0.1236	0.955
$Ca(OH)_2$	6	1.3225	0.2204	1.704
Error	18	2.3288	0.1294	
Total	27	4.0220		

4.4.11. Effect of $Ca(OH)_2$ on magnesium content of stem and leaves (%)

(Data on which Table 18 is based)

$Ca(OH)_2$ t/ha	Replication			
	1	2	3	4
2.5	0.32	0.26	0.31	0.32
5	0.23	0.26	0.34	0.22
10	0.29	0.34	0.45	0.36
15	0.38	0.39	0.38	0.39
20	0.42	0.41	0.44	0.47
25	0.40	0.55	0.43	0.38
50	0.38	0.45	0.49	0.44

4.4.11. Analysis of Variance (% Mg)

Source of Var.	DF	SS	MS	VR
Blocks	3	0.013071	0.004357	2.093
$Ca(OH)_2$	6	0.121150	0.020192	9.698 **
Error	18	0.037479	0.002082	
Total	27	0.171700		

1. 4.12. Effect of $Ca(OH)_2$ on sodium content of stem and leaves (%)

(Data on which Table 18 is based)

$Ca(OH)_2$ (t/ha)	Replication			
	1	2	3	4
2.5	0.95	1.25	0.60	0.80
5	0.70	0.75	0.60	0.75
10	0.60	1.25	0.75	0.75
15	0.60	0.75	0.70	1.15
20	2.90	1.15	1.45	1.15
25	2.05	1.55	2.00	0.80
50	1.85	0.40	0.40	0.50

1. 4.12. Analysis of Variance (% Na)

Source of Var.	DF	SS	MS	VR
Blocks	3	1.1660	0.3887	1.702
$Ca(OH)_2$	6	3.9946	0.6658	2.916*
Error	18	4.1096	0.2283	
Total	27	9.2703		

1.4.13. Effect of Ca(OH)2 on molybdenum content of stem and leaves (ppm)

(Data on which Table 18 is based)

Ca(OH)2 (t/ha)	Replication			
	1	2	3	4
0	0.90	1.20	1.20	2.50
2.5	0.30	1.00	1.60	1.10
5	0.90	1.20	1.40	1.20
10	2.00	5.50	4.10	1.90
15	1.60	4.90	2.30	1.80
20	2.80	5.60	3.80	4.00
25	5.00	6.30	4.60	5.00
50	4.30	9.80	5.40	6.40

1.4.13. Analysis of Variance (ppm Mo)

Source of Var.	DF	SS	MS	VR
Blocks	3	20.3775	6.7925	6.831
$Ca(OH)_2$	7	111.5200	15.9314	16.021**
Error	21	20.8825	0.9944	
Total	31	152.7800		

1.4.14. Effect of $Ca(OH)_2$ on boron content of stem and leaves (ppm)

(Data on which Table 18 is based)

$Ca(OH)_2$ (t/ha)	Replication			
	1	2	3	4
2.5	46	51	33	44
5	33	31	30	28
10	39	27	31	29
15	23	33	31	26
20	35	36	22	29
25	33	42	30	32
50	31	35	20	30

1. 4.14. Analysis of Variance (ppm B)

Source of Var.	DF	SS	MS	VR
Blocks	3	276.14	92.05	4.277
$Ca(OH)_2$	6	653.50	108.92	5.061
Error	18	387.36	21.52	
Total	27	1317.00		

1.4.15. Effect of Ca(OH)2 on copper content of stem and leaves (ppm)

(Data on which Table 18 is based)

Ca(OH)2 (t/ha)	Replication			
	1	2	3	4
0	9.0	15.0	5.0	20.0
2.5	10.0	6.5	6.0	6.5
5	8.7	8.0	5.5	6.5
10	19.5	7.0	7.0	5.5
15	8.0	6.8	12.5	6.6
20	5.8	20.5	7.5	20.0
25	14.5	8.5	25.5	25.0
50	7.0	14.4	9.0	62.0

1.4.15. Analysis of Variance (ppm Cu)

Source	DF	SS	MS	VR
Blocks	3	458.9	153.0	1.409
$Ca(OH)_2$	7	910.9	130.1	1.198
Error	21	2280.4	108.6	
Total	31	3650.2		

1.4.16. Effect of $Ca(OH)_2$ on zinc content of stem and leaves (ppm)

(Data on which Table 18 is based)

$Ca(OH)_2$	Replication			
(t/ha)	1	2	3	4
2.5	160	160	157	160
5	73	78	88	62
10	64	48	62	58
15	56	42	64	50
20	37	37	47	54
25	47	64	37	100
50	23	59	32	48

1.4.16. Analysis of Variance (ppm Zn)

Source	DF	SS	MS	VR
Blocks	3	380.7	126.9	0.622
$Ca(OH)_2$	6	40196.0	6699.3	32.853
Error	18	3670.6	203.9	
Total	27	44247.2		

1.1.17. Effect of Ca(OH)2 on manganese content of stem and leaves (ppm)

(Data on which Table 18 is based)

Ca(OH)2	Replication			
(t/ha)	1	2	3	4
2.5	55	32	30	50
5	5	10	5	10
10	30	15	15	30
15	32	35	64	40
20	80	70	30	70
25	75	117	80	50
50	67	112	83	78

1.4.17. Analysis of Variance (ppm Mn)

Source of Var.	DF	SS	MS	VR
Blocks	3	546.4	182.1	0.576
$Ca(OH)_2$	6	19946.4	3324.4	10.518
Error	18	5689.1	316.1	
Total	27	26181.9		

1.4.18. Effect of $Ca(OH)_2$ on the dry matter yield of stem and leaves (g/pot)

(Data on which Table 19 is based)

$Ca(OH)_2$	Replication					
	1	2	3	4	5	6
Broadcast (t/ha)						
Zero	1.65	2.60	2.75	2.18	1.07	1.41
2.5	6.30	5.53	6.92	5.18	5.81	6.26
5	7.20	10.40	6.97	5.46	6.70	4.27
10	10.32	7.21	7.35	8.08	9.72	7.82
15	11.82	12.62	13.51	10.03	12.58	9.24
20	12.87	15.42	13.66	12.51	11.94	9.97
25	15.23	19.83	18.80	13.11	16.06	15.13
Contact (kg/ha)						
100	3.31	4.25	2.50	3.39	3.11	3.36
200	3.30	2.85	3.48	3.65	3.54	2.98
400	3.85	5.93	5.49	4.28	4.92	2.87
600	4.08	4.95	4.76	4.10	4.17	4.21

1.4.18. Analysis of Variance - Yield of stem and leaves (logs*)

Source of Var.	DF	SS	MS	F
Blocks	5	0.6392	0.1278	4.1
$Ca(OH)_2$	10	26.3782	2.6378	84.1
Error	50	1.5687	0.0314	
Total	65	28.5861		

* In this analysis yields (g/pot) are shown as the logarithmic transformation to base e.

APPENDIX 2

THE EFFECT OF LEACHING ON THE MORPHINE CONTENT OF CAPSULES

2.1. Effect of leaching and related treatments on morphine concentration of ground capsules (%)

(Data on which Table 20 is based)

Treatment	Replication		
	1	2	3
(i) 50% Dry capsule + 50% Water	0.50	0.48	0.51
(ii) 20% " " + 80% Water	0.50	0.53	0.57
(iii) 20% " " + 80% Water + Leaching	0.19	0.22	0.24
(iv) 20% " " + 80% Water + 2 Drying Cycles	0.54	0.60	0.55
(v) Air Dry Capsule	0.55	0.55	0.58
Leachate from (iii) *	0.42	0.43	0.41

* The morphine percentages of the leachate from Treatment (iii) were not included in the analysis.

2.1. Analysis of Variance - morphine concentration of leached ground capsules (%)

Source of Var.	DF	SS	MS	F. Ratio
Treatment	4	0.257	0.064	64**
Error	10	0.008	0.001	
Total	14	0.265		

2.2. Effect of Time of Harvest and Leaching on Intact Capsule Morphine and Immersion Water Morphine

2.2.1. Effect of Time of harvest and leaching on intact capsule morphine concentration

(Data on which Table 21 is based)

Replication	Time of Harvest			
	Two weeks after full bloom			
	L0	L1	L2	L3
1	0.69	0.64	0.75	0.43
2	0.88	0.54	0.60	0.70
3	0.54	0.48	0.45	0.56
4	0.94	0.70	0.57	1.25
	Four weeks after full bloom			
1	1.39	1.20	1.50	0.96
2	0.98	1.17	1.10	1.24
3	1.37	1.01	0.89	0.90
4	1.21	1.08	1.11	0.97
	Six weeks after full bloom			
1	0.82	1.00	1.08	1.05
2	1.16	1.02	0.80	0.91
3	1.10	1.35	1.16	1.21
4	1.75	1.27	1.41	0.74

L = Length of capsule immersion time
L0 = zero minutes L2 = 44.8 minutes
L1 = 6.7 " L3 = 300 "

2.2.1. Analysis of Variance - morphine concentration of leached intact capsules (%)

Source of Var.	DF	SS	MS	VR
Length of Immersion	3	0.1666	0.0555	1.099
Time of Harvest	2	2.1769	1.0884	21.539
Time x Length	6	0.1527	0.0254	0.504
Error	36	1.8193	0.0505	
Total	47	4.3156		

2.2.2. Effect of time of harvest and leaching of intact capsules on weight of morphine in immersion water (mg).

(Data on which Table 22 is based)

Replication	Time of Harvest		
	Four weeks after full bloom		
	L1	L2	L3
1	0.00	0.07	0.07
2	0.07	0.03	0.93
3	0.00	0.00	0.40
4	0.00	0.07	0.07
	Six weeks after full bloom		
1	0.04	0.04	1.16
2	0.04	0.12	1.32
3	0.16	0.16	1.36
4	0.12	0.08	1.08

L = Length of capsule immersion time
L1 = 6.7 minutes
L2 = 44.8 minutes
L3 = 300 minutes

2.2.2. Analysis of Variance - weight of morphine in immersion water (mg)

Source of Var.	DF	SS	MS	VR
Length of Immersion	2	2.8922	1.4461	45.44**
Time of Harvest	1	0.6567	0.6567	20.64**
Time x Length	2	0.8482	0.4241	13.33**
Error	18	0.5728	0.0318	
Total	23	4.9699		

APPENDIX 3

THE EFFECT OF TIME OF HARVEST

3.1. The Effect of Time of Harvest on Capsule Morphine

3.1.1. Effect of time of harvest on dry weight of individual terminal capsules (g)

(Data on which Table 23 is based)

Harvest Number										
1	2	3	4	5	6	7	8	9	10	11
1.87	2.53	2.46	2.52	2.89	2.57	2.01	1.63	1.74	2.02	1.80
2.25	1.99	1.73	1.91	2.32	2.05	2.04	2.65	2.04	1.10	2.31
2.86	2.37	1.82	1.53	2.45	3.17	3.19	2.95	1.76	1.84	1.21
1.44	3.93	1.72	1.22	2.16	2.42	1.90	1.77	2.03	2.00	2.17
1.85	1.51	1.68	1.71	3.16	1.95	1.76	1.99	2.58	1.76	1.99
3.46	2.49	2.75	1.76	1.97	1.43	1.36	2.21	1.46	1.57	0.99
1.41	3.15	1.33	1.61	1.51	2.39	1.42	2.20	2.13	2.41	2.44
1.20	1.93	2.31	2.33	1.47	2.45	2.70	1.65	1.56	1.50	1.88
1.78	1.86	1.60	2.70	2.06	2.42	2.37	1.36	1.16	2.09	2.91
1.89	1.75	2.65	1.58	1.71	1.66	2.02	1.74	1.58	1.91	2.75
	3.19	1.68	2.20	1.80	2.13	2.75	1.42	1.12	2.09	2.02
	2.58	1.98	3.19	3.50	2.46	1.67	1.15	3.03	4.39	1.57
	2.43	1.65	1.55	2.15	3.53	2.90	1.77	2.15	4.32	2.59
	3.25	2.15	2.07	3.05	2.34	1.34	2.51	1.60	2.11	2.03
	1.72	2.05	1.79	2.52	2.74	2.12	2.08	1.46	2.11	1.95
	2.62	2.39	2.34	2.29	1.78	3.10	2.21		1.62	2.34
	1.57	1.43	1.88	2.22	2.24	1.71	1.38		2.45	
	2.15			1.72			1.95			

3.1.1. Analysis of Variance - dry weight of terminal capsules (g)

Source of Var.	DF	SS	MS	VR
Time of Harvest	10	5.3539	0.5354	1.6
Error	169	57.4934	0.3402	
Total	179			

3.1.2. Effect of time of harvest on morphine concentration of terminal capsules (%)

(Data on which Table 23 and Figure 2 are based)

Harvest No.	Replication 1	2	3
1	0.36	0.42	0.43
2	0.58	0.65	0.60
3	0.79	1.16	0.97
4	1.05	1.14	0.94
5	1.17	1.14	1.42
6	1.23	1.37	1.60
7	1.35	1.39	1.20
8	1.43	1.26	1.41
9	0.92	1.08	1.07
10	1.00	0.82	0.84
11	0.94	0.73	0.59

3.1.2. Analysis of Variance - morphine concentration of terminal capsules(%)

Source of Var.	DF	SS	MS	VR
Time of Harvest	10	3.1152	0.3115	19.8**
Error	22	0.3465	0.0158	
Total	32	3.4618		

3.1.3. Effect of time of harvest on morphine concentration of lateral capsules (%)

(Data on which Table 23 and Fig. 2 are based)

Harvest No.	Replication 1	2	3
1	N.A.	N.A.	N.A.
2	0.39	0.53	0.58
3	1.06	1.08	1.13
4	1.16	1.36	1.00
5	0.85	1.61	1.35
6	0.92	1.43	1.62
7	N.A.	N.A.	N.A.
8	1,32	1.14	1.40
9	N.A.	N.A.	N.A.
10	0.91	0.70	0.90
11	0.84	0.53	0.48

N.A. = Not available

3.1.3. Analysis of Variance - morphine concentration of lateral capsules(%)

Source of Var.	DF	SS	MS	VR
Time of Harvest	7	2.2730	0.3247	6.6
Error	16	0.7871	0.0492	
Total	23	3.0601		

3.2. Effect of time of harvest on the morphine concentration (%) and morphine yield (kg/ha) of terminal, lateral and total capsules from the 1.1 P1 non-sprayed treatment

(Data on which Tables 25, 29, 46, are based)

Harvest No.	Replication	Terminal Capsules Morphine %	Terminal Capsules Morphine kg/ha	Lateral Capsules Morphine %	Lateral Capsules Morphine kg/ha	Total Capsules Morphine %	Total Capsules Morphine kg/ha
1	1	0.58	5.7	0.92	2.8	0.66	8.5
	2	0.56	6.0	0.74	2.7	0.61	8.7
	3	0.72	4.8	1.01	2.0	0.77	6.8
	4	0.69	6.7	1.25	3.2	0.81	10.0
2	1	0.66	9.1	0.69	5.6	0.67	14.7
	2	0.66	8.6	0.64	5.6	0.65	14.2
	3	0.62	7.4	0.77	2.8	0.66	10.2
	4	0.77	9.9	0.71	7.9	0.74	17.8
3	1	0.62	5.0	0.80	2.1	0.67	7.1
	2	0.62	7.0	0.86	4.4	0.70	11.4
	3	0.76	7.5	0.84	2.9	0.78	10.4
	4	0.78	9.9	1.02	5.9	0.85	15.8
4	1	0.93	9.0	0.87	8.1	0.90	17.1
	2	0.54	4.2	0.67	2.8	0.66	7.0
	3	0.91	10.1	0.74	6.5	0.83	16.6
	4	0.79	8.1	0.74	4.8	0.77	12.9
5	1	0.99	8.3	1.12	8.1	1.05	16.4
	2	0.77	5.8	0.82	3.3	0.79	9.1
	3	1.03	9.0	0.96	3.9	1.01	12.9
	4	0.87	8.2	0.93	2.3	0.88	12.1
6	1	1.11	6.5	1.22	6.1	1.15	12.6
	2	1.02	9.2	1.03	5.9	1.02	15.1
	3	1.11	11.5	0.96	5.6	1.05	17.1
	4	0.97	8.5	0.97	3.2	0.83	11.7
7	1	1.14	8.6	1.09	4.6	1.13	13.2
	2	1.14	8.9	1.09	5.0	1.13	13.9
	3	0.79	7.5	0.83	5.0	0.81	12.5
	4	1.10	9.9	1.12	9.1	1.17	19.0
8	1	0.83	5.9	0.83	3.9	0.83	9.8
	2	0.98	7.6	1.06	4.9	1.00	12.5
	3	0.98	8.3	1.16	10.7	1.07	19.0
	4	0.98	6.0	1.12	2.3	1.00	8.3
9	1	0.53	4.1	0.79	3.4	0.63	7.5
	2	0.72	5.0	0.75	1.0	0.73	6.0
	3	0.99	7.4	0.73	3.1	0.89	10.5
	4	0.75	5.8	0.86	5.6	0.80	11.4
10	1	0.66	5.5	0.60	2.2	0.63	7.7
	2	1.18	7.8	1.09	6.5	1.13	14.3
	3	0.94	7.5	1.01	3.9	0.95	11.4
	4	0.70	5.1	1.01	1.1	0.74	6.2
11	1	0.60	3.7	0.78	3.3	0.67	7.0
	2	0.75	4.9	0.85	3.9	0.79	8.8
	3	0.89	6.6	0.94	5.1	0.91	11.7
	4	0.69	5.7	0.81	5.3	0.74	11.0
12	1	0.65	3.7	0.73	2.9	0.68	6.6
	2	0.71	4.3	0.67	1.7	0.69	6.0
	3	1.01	7.5	0.95	5.5	0.93	13.0
	4	0.82	5.6	0.96	2.3	0.86	7.9

3.3. Effect of time of harvest on the morphine concentration (%) and morphine yield (kg/ha) of terminal, lateral and total capsules from the M71 sprayed treatment

(Data on which Tables 25,29,46 are based)

Harvest No.	Replication	Terminal Capsules Morphine %	Terminal Capsules Morphine kg/ha	Lateral Capsules Morphine %	Lateral Capsules Morphine kg/ha	Total Capsules Morphine %	Total Capsules Morphine kg/ha
1	1	0.62	6.6	0.91	2.7	0.68	9.3
	2	0.60	6.7	1.37	1.5	0.64	8.2
	3	0.63	6.1	1.01	1.8	0.69	7.9
	4	0.66	7.3	1.05	3.1	0.75	10.4
2	1	0.71	8.8	0.64	4.1	0.69	12.9
	2	0.65	8.1	0.65	2.6	0.65	10.7
	3	0.69	8.8	0.80	4.9	0.72	13.7
	4	0.74	9.2	0.94	10.1	0.83	19.3
3	1	0.74	8.5	0.92	6.8	0.82	15.3
	2	0.66	7.1	0.88	10.4	0.78	17.5
	3	0.69	8.8	0.80	4.9	0.72	13.7
	4	0.74	9.2	0.94	10.1	0.83	19.3
4	1	0.66	7.3	0.70	6.0	0.67	13.3
	2	0.75	7.4	0.83	3.4	0.77	10.8
	3	0.72	7.1	0.85	5.0	0.76	12.1
	4	0.79	7.7	0.83	4.8	0.80	12.5
5	1	1.33	11.6	0.83	5.1	1.12	16.7
	2	1.18	13.2	1.15	8.0	1.16	21.2
	3	1.00	8.1	1.47	2.3	1.07	10.4
	4	1.08	9.6	1.02	8.7	1.05	18.3
6	1	1.06	9.6	1.15	8.9	1.10	18.5
	2	1.22	12.9	1.40	13.0	1.30	25.9
	3	1.08	9.0	0.98	5.5	1.04	14.5
	4	1.03	9.9	1.03	3.1	1.01	11.0
7	1	1.04	7.6	1.21	8.1	1.12	15.7
	2	1.01	8.1	1.10	8.5	1.04	13.6
	3	0.98	9.4	1.11	8.3	1.04	17.7
	4	1.02	7.9	1.13	6.3	1.07	14.2
8	1	0.75	5.5	0.79	8.0	0.88	13.5
	2	0.97	11.5	0.91	5.9	0.95	17.4
	3	0.92	7.6	1.12	5.2	0.99	12.8
	4	1.07	8.5	0.99	5.3	1.04	13.8
9	1	0.89	6.6	0.91	7.2	0.90	13.2
	2	0.82	7.5	0.80	4.8	0.81	12.3
	3	1.10	8.2	0.96	4.5	1.04	12.7
	4	0.99	8.0	0.74	6.6	0.86	14.6
10	1	0.80	6.7	0.69	3.0	0.76	9.7
	2	0.99	8.2	0.85	9.2	0.91	17.4
	3	0.93	8.8	1.06	6.3	0.98	15.1
	4	1.03	10.5	0.84	3.6	0.97	14.1
11	1	0.85	6.7	1.14	7.8	0.98	14.5
	2	0.83	5.2	1.06	8.8	0.96	14.0
	3	0.81	6.7	1.03	3.3	0.87	10.0
	4	0.87	6.5	0.86	3.3	0.86	9.8
12	1	0.67	4.8	0.93	3.9	0.77	8.7
	2	0.95	8.6	1.03	10.7	1.00	19.3
	3	0.80	6.3	0.80	2.7	0.79	9.0
	4	1.05	8.6	0.90	5.0	0.98	13.6

3.4. Effect of time of harvest on the morphine concentration (%) and morphine yield of stem + leaves, total plant and total plant less seed from one of 1 21 non-sprayed treatment
(Data on which Tables 27, 28, 29, 48, 49 are based)

Harvest No.	Replication	Stem and Leaves Morphine %	Stem and Leaves Morphine kg/ha	Total Plant Morphine %	Total Plant Morphine kg/ha	Total Plant - Seed Morphine %	Total Plant - Seed Morphine kg/ha
1	1	0.06	4.9	0.14	13.4	0.14	13.4
	2	0.07	6.3	0.14	15.0	0.14	15.0
	3	0.07	4.8	0.14	11.6	0.15	11.6
	4	0.05	3.5	0.15	13.5	0.15	13.5
2	1	0.04	3.6	0.15	18.3	0.16	18.3
	2	0.04	4.0	0.14	18.2	0.15	18.2
	3	0.06	5.0	0.14	15.2	0.15	15.2
	4	0.05	5.3	0.16	23.1	0.18	23.1
3	1	0.06	3.2	0.14	10.3	0.16	10.3
	2	0.08	6.8	0.16	18.2	0.18	18.2
	3	0.13	5.9	0.24	16.3	0.28	16.3
	4	0.12	10.2	0.22	26.0	0.25	26.0
4	1	0.06	4.9	0.16	22.0	0.22	22.0
	2	0.07	3.1	0.16	10.1	0.19	10.1
	3	0.10	8.4	0.19	25.0	0.24	25.0
	4	0.09	6.7	0.17	19.6	0.22	19.6
5	1	0.07	5.1	0.20	21.5	0.24	21.5
	2	0.09	5.9	0.17	15.0	0.20	15.0
	3	0.07	3.8	0.19	16.7	0.25	16.7
	4	0.09	5.4	0.19	17.5	0.24	17.5
6	1	0.11	6.0	0.23	18.6	0.29	18.6
	2	0.08	5.4	0.19	20.5	0.25	20.5
	3	0.10	7.6	0.22	24.7	0.27	24.7
	4	0.05	2.7	0.17	14.4	0.22	14.4
7	1	0.05	2.5	0.20	15.7	0.26	15.7
	2	0.07	4.3	0.20	18.2	0.25	18.2
	3	0.08	6.3	0.17	18.8	0.20	18.8
	4	0.06	4.1	0.22	23.1	0.27	23.1
8	1	0.04	2.0	0.15	11.8	0.20	11.8
	2	0.04	2.3	0.17	14.8	0.21	14.8
	3	0.04	2.8	0.19	21.8	0.25	21.8
	4	0.06	2.2	0.17	10.5	0.24	10.5
9	1	0.08	4.8	0.14	12.3	0.17	12.3
	2	0.06	2.7	0.13	8.7	0.16	8.7
	3	0.03	1.7	0.14	12.2	0.18	12.2
	4	0.09	5.3	0.19	16.7	0.23	16.7
10	1	0.03	1.4	0.13	9.1	0.16	9.1
	2	0.03	1.3	0.20	15.6	0.29	15.6
	3	0.02	1.1	0.15	12.5	0.20	12.5
	4	0.05	2.5	0.12	8.7	0.15	8.7
11	1	0.04	2.2	0.11	9.2	0.14	9.2
	2	0.04	2.5	0.12	11.3	0.15	11.3
	3	0.04	2.7	0.15	14.4	0.18	14.4
	4	0.06	4.0	0.16	15.0	0.19	15.0
12	1	0.07	2.1	0.17	8.7	0.22	11.9
	2	0.03	1.2	0.12	7.2	0.15	22.2
	3	0.05	2.0	0.20	15.0	0.28	13.2
	4	0.05	2.1	0.15	10.3	0.20	14.2

3.5. Effect of time of harvest on the morphine concentration (%) and morphine yield (kg/ha) of stem + leaves, total plant and total plant less seed from the N1P1 sprayed treatment.

(Data on which Tables 27, 28 29, are based) 48, 49

Harvest No.	Replication	Stem & Leaves Morphine %	Stem & Leaves Morphine kg/ha	Total Plant Morphine %	Total Plant Morphine kg/ha	Total Plant - Seed Morphine %	Total Plant - Seed Morphine kg/ha
1	1	0.10	12.9	0.17	22.2	0.18	22.2
	2	0.13	12.0	0.18	20.2	0.19	20.2
	3	0.11	8.2	0.18	16.0	0.19	16.0
	4	0.12	10.4	0.20	20.8	0.21	20.8
2	1	0.06	5.1	0.16	18.0	0.18	18.0
	2	0.06	4.8	0.14	15.5	0.16	15.5
	3	0.05	5.3	0.15	20.4	0.16	20.4
	4	0.08	6.2	0.16	16.9	0.18	16.9
3	1	0.07	5.7	0.17	20.9	0.21	20.9
	2	0.13	16.7	0.20	34.1	0.22	34.1
	3	0.05	3.8	0.16	17.5	0.18	17.5
	4	0.06	7.4	0.17	26.7	0.18	26.7
4	1	0.06	5.5	0.15	18.8	0.17	18.8
	2	0.07	4.4	0.16	15.2	0.20	15.2
	3	0.07	5.0	0.13	17.1	0.20	17.1
	4	0.08	5.9	0.16	18.4	0.21	18.4
5	1	0.08	5.7	0.21	22.4	0.26	22.4
	2	0.07	6.2	0.21	27.5	0.26	27.5
	3	0.16	8.0	0.24	19.4	0.29	19.4
	4	0.14	10.1	0.25	28.4	0.32	28.4
6	1	0.04	3.2	0.18	21.7	0.23	21.7
	2	0.05	4.9	0.20	30.8	0.26	30.8
	3	0.08	5.6	0.19	20.1	0.24	20.1
	4	0.10	5.1	0.20	16.1	0.26	16.1
7	1	0.04	2.6	0.19	18.3	0.24	18.3
	2	0.04	2.5	0.17	16.1	0.22	16.1
	3	0.05	3.9	0.17	21.6	0.23	21.6
	4	0.05	3.0	0.19	17.2	0.24	17.2
8	1	0.08	4.1	0.20	17.6	0.27	17.6
	2	0.02	1.4	0.17	18.8	0.21	18.8
	3	0.02	1.1	0.16	13.9	0.20	13.9
	4	0.03	1.7	0.17	15.5	0.22	15.5
9	1	0.05	3.3	0.16	16.5	0.21	16.5
	2	0.03	2.0	0.14	14.3	0.18	14.3
	3	0.03	1.6	0.17	14.3	0.22	14.3
	4	0.04	2.8	0.16	17.4	0.20	17.4
10	1	0.03	1.8	0.13	11.5	0.16	11.5
	2	0.04	3.2	0.16	20.6	0.21	20.6
	3	0.03	2.1	0.16	17.2	0.21	17.2
	4	0.04	2.8	0.15	16.9	0.20	16.9
11	1	0.04	2.2	0.18	16.7	0.24	16.7
	2	0.04	2.1	0.19	16.1	0.24	16.1
	3	0.04	2.4	0.14	12.4	0.18	12.4
	4	0.02	1.1	0.14	10.9	0.18	10.9
12	1	0.07	3.2	0.16	11.9	0.21	11.9
	2	0.06	2.9	0.23	22.2	0.33	22.2
	3	0.09	9.2	0.18	13.2	0.23	13.2
	4	0.02	0.9	0.18	14.5	0.25	14.5

3.6. Analysis of Variance - Effect of time of harvest, fertiliser and spray treatments on dry matter yield of terminal capsules (g/m^2)

Source of Var.	DF	SS	MS	VR
Treatments*	7	6095.146	870.735	3.910
Block	3	219.590	73.196	.329
Error (1)	21	4676.231	222.707	
Time	11	73081.231	6643.748	45.589
Time X Treatments	77	16381.475	212.746	1.460
Error (2)	264	38473.109	145.731	
Total	383	138927.411		

In appendices 3.6. to 3.17. "Treatments" = the four fertiliser and two spray treatments.

3.7. Analysis of Variance - Effect of time of harvest, fertiliser and spray treatments on dry matter yield of lateral capsules (g/m^2)

Source of Var.	DF	SS	MS	VR
Treatments	7	57435.576	8205.082	21.085
Block	3	2829.436	943.145	2.424
Error (1)	21	8172.054	389.145	
Time	11	17590.974	1599.179	4.798
Time X Treatments	77	32536.790	422.815	1.269
Error (2)	264	87984.926	333.276	
Total	383	206569.759		

3.8. Analysis of Variance - Effect of time of harvest, fertiliser and spray treatments on dry matter yield of total capsules (g/m^2)

Source of Var.	DF	SS	MS	VR
Treatments	7	52506.868	7500.981	11.709
Block	3	4478.297	1492.765	2.330
Error (1)	21	13452.675	640.603	
Time	11	114229.856	10384.541	18.309
Time X Treatments	77	58675.859	762.024	1.344
Error (2)	264	149735.802	567.181	
Total	383	393079.459		

3.9. Analysis of Variance - Effect of time of harvest, fertiliser and spray treatments on dry matter yield of terminal seed (g/m^2)

Source of Var.	DF	SS	MS	VR
Treatments	7	31584.760	4512.108	6.532
Block	3	939.190	313.063	.455
Error (1)	21	14505.322	690.729	
Time	11	560006.989	50909.726	123.905
Time X Treatments	77	46255.799	600.724	1.462
Error (2)	264	108741.894	410.878	
Total	383	761763.956		

3.10. Analysis of Variance - Effect of time of harvest, fertiliser and spray treatments on dry matter yield of lateral seed (g/m^2)

Source of Var.	DF	SS	MS	VR
Treatments	7	37107.977	5301.139	6.846
Block	3	11401.649	3800.549	4.909
Error (1)	21	16256.595	774.137	
Time	11	108004.167	9818.560	14.211
Time X Treatments	77	57496.720	746.710	1.001
Error (2)	264	182399.496	690.907	
Total	383	412666.906		

3.11. Analysis of Variance - Effect of time of harvest, fertiliser and spray treatments on dry matter yield of total seed (g/m^2)

Source of Var.	DF	SS	MS	VR
Treatments	7	53888.784	7698.397	5.961
Block	3	16030.019	5343.339	4.137
Error (1)	21	27121.131	1291.482	
Time	11	1138427.095	103493.372	80.953
Time X Treatments	77	110902.830	1440.296	1.127
Error (2)	264	337505.701	1278.430	
Total	383	1683875.563		

3.12. Analysis of Variance - Effect of time of harvest, fertiliser and spray treatment on dry matter yield of stem and leaves (g/m^2).

Source of Var.	DF	SS	MS	VR
Treatments	7	1796291.437	256613.062	15.195
Block	3	239891.939	79963.979	4.735
Error (1)	21	354657.907	16888.471	
Time	11	3130175.866	284561.369	25.395
Time x Treatments	77	1493266.463	19393.070	1.731
Error (2)	264	2958209.595	11205.339	
Total	383	9972492.410		

3.13. Analysis of Variance - Effect of time of harvest, fertiliser and spray treatments on dry matter yield of total plant (g/m^2).

Source of Var.	DF	SS	MS	VR.
Block Stratum	3	452881	150960	6.309
Block Mainplot Stratum Spray	1	698326	698326	22.400
P	1	1459494	1469494	47.137
N	1	504825	504825	16.193
Spray x P	1	32533	32533	1.044
Spray x N	1	40510	40510	1.299
P x N	1	154116	154116	4.944
Spray x P x N	1	7728	7728	8.248
Error (1)	21	654668	31175	1.303
Time	11	2198415	199856	8.353
Time x Spray	11	405100	36827	1.539
Time x P	11	407882	37080	1.550
Time x N	11	332686	30244	1.264
Time x Spray x P	11	583683	53062	2.218
Time x Spray x N	11	388076	35280	1.474
Time x P x N	11	230863	20988	0.877
Error (2)	275	6580027	23927	
Total	383	1914813		

3.14. Analysis of Variance - Effect of time of harvest, fertiliser and spray treatments on fresh head yield (g/m^2).

Source of Var.	DF	SS	MS	VR
Treatments	7	1144534.849	163504.978	7.526
Block	3	216977.497	72325.832	3.329
Error (1)	21	456229.104	21725.195	
Time	11	55959743.853	5087249.441	209.027
Time x Treatment	77	2958900.411	38427.278	1.579
Errors (2)	264	6425171.600	24337.771	
Total	383	67161557.316		

3.15. Analysis of Variance - Effect of time of harvest, fertiliser and spray treatments on fresh yield of stem + leaves (g/m^2).

Source of Var.	DF	SS	MS	VR
Treatments	7	31165839.734	4455119.962	11.594
Block	3	6685041.253	2228347.084	5.799
Error (1)	21	8069480.986	384260.999	
Time	11	1266383416.801	115125765.163	342.904
Time x Treatment	77	59566675.643	773593.190	2.304
Error (2)	264	88634754.958	335737.708	
Total	383	146052509.378		

3.16. Analysis of Variance - Effect of time of harvest, fertiliser and spray treatments on fresh yield of total plant (g/m^2).

Source of Var.	DF	SS	MS	VR
Treatments	7	43469624.251	6209946.321	10.865
Block	3	9161447.092	3053815.697	5.343
Error (1)	21	12002864.610	571564.981	
Time	11	1808884937.265	164444085.205	322.184
Time x Treatment	77	84691235.609	1099886.176	2.155
Error (2)	264	134746759.957	510404.393	
Total	383	2092956868.788		

3.17. Analysis of Variance - Effect of time of harvest, fertiliser and spray treatments on number of carsules per metre^2 (NO/m^2).

Source of Var.	DF	SS	MS	VR
Treatments	7	52544.166	7506.309	25.992
Block	3	1106.837	368.945	1.278
Error (1)	21	6064.678	288.794	
Time	11	9146.789	831.526	2.995
Time x Treatments	77	28022.859	363.933	1.311
Error (2)	264	73302.086	277.659	
Total	383	170187.417		

3.18. Analysis of Variance - Effect of time of harvest and spray treatments on morphine concentration of terminal capsules (%)

Source of Var.	DF	SS	MS	VR
Spray	1	.061	.061	3.061
Blocks	3	.069	.023	1.168
Error (1)	3	.059	.091	
Time	11	1.887	.171	12.702**
Time x Treatments	11	.185	.016	1.249
Error (2)	66	.891	.013	
Total	95	3.155		

In appendices 3.18 to 3.28 the measurements were taken on the N1P1 sprayed and N1P1 non-sprayed treatments only.

3.19. Analysis of Variance - Effect of time of harvest and spray treatments on morphine concentration of lateral capsules (%)

Source of Var.	DF	SS	MS	VR
Spray	1	.079	.079	2.176
Blocks	3	.060	.020	.550
Error (1)	3	.109	.036	
Time	11	1.379	.125	6.990
Time x Treatments	11	.152	.013	.771
Error (2)	66	1.183	.017	
Total	95	2.964		

3.20. Analysis of Variance - Effect of time of harvest and spray treatments on morphine concentration of total capsules (%)

Source of Var.	DF	SS	MS	VR
Spray	1	.069	.069	7.591
Block	3	.034	.011	1.267
Error (1)	3	.027	.009	
Time	11	1.548	.140	12.790**
Time x Treatments	11	.109	.009	.906
Error (2)	66	.726	.011	
Total	95	2.516		

3.21. Analysis of Variance - Effect of time of harvest and spray treatments on morphine concentration of stem + leaves (%)

Source of Var.	DF	SS	MS	VR
Spray	1	.000	.000	.000
Blocks	3	.000	.000	6.765
Error (1)	3	.000	.000	
Time	11	.039	.003	7.867
Time x Treatments	11	.012	.001	2.526
Error (2)	66	.029	.000	
Total	95	.082		

3.22. Analysis of Variance - Effect of time of harvest and spray treatments on morphine concentration of total plant (%)

Source of Var.	DF	SS	MS	VR
Spray	1	.001	.001	1.585
Blocks	3	.001	.000	.305
Error (1)	3	.003	.001	
Time	11	.033	.003	5.831**
Time x Treatments	11	.008	.000	1.544
Error (2)	66	.034	.000	
Total	95	.084		

3.23. Analysis of Variance - Effect of time of harvest and spray treatments on morphine concentration of total plant less seed (%)

Source of Var.	DF	SS	MS	VR
Spray	1	.003	.003	2.115
Blocks	3	.002	.000	.471
Error (1)	3	.004	.001	
Time	11	.001	.007	7.785**
Time x Spray	11	.016	.001	1.582
Error (2)	66	.063	.000	
Total	95	.171		

3.24. Analysis of Variance - Effect of time of harvest and spray treatment on morphine yield of terminal capsules (g/m^2)

Source of Var.	DF	SS	MS	VR
Spray	1	.246	.246	5.394
Blocks	3	.185	.061	1.359
Error (1)	3	.136	.045	
Time	11	1.356	.123	6.020**
Time x Spray	11	.209	.019	.929
Error (2)	66	1.352	.020	
Total	95	3.486		

3.25. Analysis of Variance - Effect of time of harvest and spray treatment on morphine yield of lateral capsules (g/m^2)

Source of Var.	DF	SS	MS	VR
Spray	1	.412	.412	3.932
Block	3	.092	.030	.296
Error (1)	3	.314	.104	
Time	11	1.054	.095	1.911
Time x Spray	11	.592	.053	1.074
Error (2)	66	3.311	.050	
Total	95	5.776		

3.26. Analysis of Variance - Effect of time of harvest and spray treatment on morphine yield of total capsules (g/m^2)

Source of Var.	DF	SS	MS	VR
Spray	1	1.295	1.295	4.488
Block	3	.143	.047	.165
Error (1)	3	.665	.238	
Time	11	3.831	.348	3.520
Time x Spray	11	1.213	.110	1.115
Error (2)	66	6.531	.098	
Total	95	13.880		

3.27. Analysis of Variance - Effect of time of harvest and spray treatment on morphine yield of stem + leaves (,)

Source of Var.	DF	SS	MS	VR
Spray	1	.115	.115	4.323
Block	3	.043	.014	.542
Error (1)	3	.080	.026	
Time	11	3.879	.352	10.742
Time X Spray	11	.961	.087	2.662
Error (2)	66	2.166	.032	
Total	95	7.246		

3.28. Analysis of Variance - Effect of time of harvest and spray treatment on morphine yield of total plant (g/m^2)

Source of Var.	DF	SS	MS	VR
Spray	1	2.181	2.181	4.499
Block	3	.324	.108	.223
Error (1)	3	1.454	.484	
Time	11	8.499	.772	5.351
Time X Spray	11	2.162	.196	1.361
Error (2)	66	9.530	.144	
Total	95	24.151		

In appendices 3.6. to 3.17. "Treatments" = four fertiliser and two spray treatments. Analysis of Variance 3.6. to 3.28. were used to obtain error mean squares of slightly greater accuracy than those from 4.19. to 4.31. in which the Time X Spray X B X P interaction was balked in with Error (2). The error mean squares from appendices 3.6. to 3.17. were used in the calculation of l.s.d.'s in Section 4.

APPENDIX 4

THE EFFECT OF N P NUTRITION AT DIFFERENT TIMES OF HARVEST.

4.1. Effect of banded N P fertiliser on dry matter yield of whole plants eight weeks after sowing (g/m^2)

(Data on which Table 30 is based)

Treatments	Replication			
	1	2	3	4
No Po	2.8	2.3	2.3	2.7
N1 Po	2.6	1.9	1.5	2.3
No P1	7.9	6.3	5.6	5.9
N1 P1	10.5	9.0	9.9	8.5

4.1. Analysis of Variance - Effect of banded N P fertiliser on dry matter yield of whole plants eigth weeks after sowing (g/m^2)

Source of Var.	DF	SS	MS	VR
Blocks	3	3.64	1.21	3.9
N	1	6.76	6.76	21.8 **
P	1	127.69	127.69	411.9 **
N X P	1	12.25	12.25	39.5 **
Error	9	2.81	0.31	
Total	15	153.15		

4.2. Effect of banded N P fertiliser on dry matter yield of whole plants twelve weeks after sowing (g/m^2)

(Data on which Table 31 is based)

Treatments	Replication			
	1	2	3	4
No Po	65.7	71.3	67.3	79.0
N1 Po	88.0	78.3	66.3	88.9
No P1	186.2	169.1	141.6	160.2
N1 P1	286.6	320.4	260.4	280.8

4.2. Analysis of variance - Effect of banded N P fertiliser on dry matter yield of whole plants twelve weeks after sowing (g/m^2)

Source of Var.	DF	SS	MS	VR
Blocks	3	1608.0	536.0	2.79
N	1	17509.9	17509.9	91.2 **
P	1	90075.0	90075.0	469.4 **
N X P	1	12819.9	12819.9	66.8 **
Error	9	1727.4	191.9	
Total	15	123740.2		

4.3. Effect of time of harvest on the dry matter yield of terminal, lateral and total capsules and seed from the NOPO non-sprayed treatment (g/m^2)

(Data on which Tables 33 to 38 are based)

Harvest No.	Replic-ation	Term. Caps.		Lat. Caps.		Tot. Caps.	
		Caps.	Seed	Caps.	Seed	Caps.	Seed
1	1	85.8	20.3	13.0	1.6	98.8	21.9
	2	91.8	20.8	9.4	1.3	101.2	22.1
	3	60.4	19.4	11.4	2.3	71.8	21.7
	4	77.0	9.4	12.0	1.6	89.0	11.0
2	1	117.2	88.2	21.4	11.3	138.6	99.5
	2	117.7	70.2	27.5	12.2	145.2	82.4
	3	89.9	51.0	3.5	0.6	93.4	51.6
	4	97.4	69.6	0	0	97.4	69.6
3	1	95.9	83.2	0	0	95.9	83.2
	2	151.3	125.2	1.9	0.6	153.2	125.8
	3	126.3	112.9	17.1	8.5	143.4	121.4
	4	145.8	144.0	33.0	28.2	178.8	172.2
4	1	133.3	169.9	8.3	8.9	141.6	178.8
	2	93.5	132.2	0	0	93.5	132.2
	3	79.1	118.6	4.7	4.7	83.8	123.3
	4	101.5	151.1	13.1	1.1	114.6	152.2
5	1	86.3	163.8	23.9	30.2	110.2	194.0
	2	88.5	175.3	39.2	57.7	127.7	233.0
	3	74.1	134.5	18.2	29.1	92.3	163.6
	4	97.9	174.4	19.9	19.9	117.8	194.3
6	1	103.8	174.0	11.4	9.0	115.2	183.0
	2	84.6	151.2	15.1	28.0	99.7	179.2
	3	82.6	138.1	4.7	0.6	87.3	138.7
	4	78.7	145.8	17.1	2.8	95.8	148.5
7	1	78.0	137.7	36.7	37.2	114.7	174.9
	2	115.9	173.6	24.1	26.3	140.0	199.9
	3	90.3	154.6	19.5	23.6	109.8	178.2
	4	86.4	169.4	13.8	17.1	100.2	186.5
8	1	105.8	211.1	71.7	146.7	177.5	357.8
	2	89.1	182.5	49.7	85.3	138.8	267.8
	3	79.0	148.4	29.7	51.0	108.7	199.4
	4	92.6	201.8	31.2	40.6	123.8	242.3
9	1	89.7	189.1	12.8	21.4	102.5	210.5
	2	77.5	159.1	27.6	51.0	105.1	210.1
	3	84.3	164.8	18.0	32.9	102.3	197.7
	4	102.6	175.6	14.8	27.4	117.4	202.9
10	1	105.0	174.5	29.5	54.5	134.5	229.0
	2	106.2	193.5	27.0	31.1	132.2	224.6
	3	99.8	183.0	29.6	34.8	129.4	217.8
	4	99.1	184.2	14.6	27.4	113.7	211.6
11	1	71.3	139.9	48.4	102.1	119.7	242.0
	2	93.6	176.9	15.7	18.6	109.3	195.5
	3	81.1	153.9	25.0	45.8	106.1	199.7
	4	79.0	139.9	54.1	109.2	133.1	249.1
12	1	97.4	149.8	37.4	49.0	134.9	198.7
	2	74.8	145.8	9.9	23.1	84.7	168.9
	3	79.5	168.5	19.6	29.7	99.1	198.2
	4	66.2	137.1	13.8	23.9	80.0	161.0

4.4. Effect of time of harvest on the dry matter yield of terminal, lateral and total capsules and seed from the N1P0 non-sprayed treatment (g/m^2)
(Data on which Tables 33 to 38 are based)

Harvest No.	Replic-ation	Term. Caps.		Lat. Caps.		Tot. Caps.	
		Caps.	Seed	Caps.	Seed	Caps.	Seed
1	1	82.0	28.9	3.5	0.6	85.6	29.5
	2	108.5	31.6	17.4	1.2	125.9	32.9
	3	74.3	25.2	0	0	74.3	25.2
	4	108.2	27.1	13.2	3.3	121.4	30.4
2	1	136.8	85.5	12.5	0	149.3	85.5
	2	118.3	86.9	16.7	1.6	135.0	88.6
	3	122.6	73.0	25.1	7.4	147.7	80.4
	4	128.3	79.0	30.7	4.2	159.0	83.2
3	1	112.8	90.6	33.0	18.0	145.8	108.6
	2	123.6	125.4	69.6	54.0	193.2	179.4
	3	134.0	116.9	39.9	18.2	173.9	35.1
	4	123.8	134.7	77.0	56.2	200.8	190.8
4	1	73.1	109.0	20.9	34.8	94.0	143.8
	2	81.0	112.3	23.2	11.9	104.2	124.2
	3	73.8	95.0	53.1	81.0	126.9	176.0
	4	74.0	111.7	13.7	4.9	87.7	116.6
5	1	96.7	157.1	31.9	37.3	128.6	194.4
	2	93.1	153.3	23.0	19.6	116.1	176.9
	3	96.2	147.7	35.9	29.6	132.1	177.3
	4	68.5	112.0	25.0	34.5	93.5	146.5
6	1	63.6	113.2	41.4	65.6	105.0	178.8
	2	93.6	163.7	30.4	44.1	124.0	207.8
	3	84.2	132.6	23.1	33.6	107.3	166.1
	4	88.9	140.8	13.7	17.7	102.6	158.5
7	1	93.0	172.2	37.2	66.0	130.2	238.2
	2	95.6	130.7	24.8	27.0	120.4	157.7
	3	81.2	125.4	9.0	8.4	90.2	133.8
	4	90.7	170.8	7.8	12.3	98.5	183.1
8	1	81.9	134.3	14.3	14.3	96.2	148.6
	2	99.3	181.0	34.8	58.2	134.1	239.2
	3	109.2	163.5	24.4	37.8	133.6	201.3
	4	65.0	108.2	5.7	9.4	70.7	117.5
9	1	84.8	172.8	29.7	47.5	114.5	220.3
	2	71.4	133.6	41.6	64.3	113.0	197.8
	3	76.4	149.5	26.7	40.5	103.1	190.0
	4	83.5	127.2	19.2	24.0	102.7	151.2
10	1	93.5	165.2	29.1	41.4	122.6	206.6
	2	87.4	155.5	16.6	28.6	104.0	184.1
	3	92.2	175.4	9.5	8.5	101.7	183.9
	4	80.3	154.0	2.8	7.2	83.1	161.2
11	1	68.9	130.5	18.5	20.7	87.4	151.2
	2	78.8	130.5	43.7	65.7	122.5	196.2
	3	102.9	141.1	48.5	73.5	151.4	214.6
	4	71.6	119.7	50.0	77.4	121.6	197.1
12	1	85.7	163.2	22.4	15.8	108.1	179.0
	2	83.3	142.1	16.2	27.4	99.5	169.5
	3	66.7	129.7	29.0	48.3	95.7	178.0
	4	65.9	126.4	32.0	34.3	97.9	160.7

4.5. Effect of time of harvest on the dry matter yield of terminal, lateral and total capsules and seed from the 10 P1 non-sprayed treatment (g/m²)
(Data on which Tables 33 and 38 are based)

Harvest No.	Replication	Term. Caps.		Lat. Caps.		Tot. Caps.	
		Caps.	Seed	Caps.	Seed	Caps.	Seed
1	1	96.7	32.8	44.2	6.2	140.9	39.0
	2	77.8	24.3	14.6	1.6	92.4	25.9
	3	108.6	29.7	26.3	2.2	134.9	31.9
	4	85.8	24.4	11.0	1.2	96.8	25.5
2	1	131.6	113.3	34.8	16.5	166.4	129.8
	2	118.6	76.4	54.1	19.8	172.7	96.2
	3	118.0	69.6	5.9	0.6	123.9	70.2
	4	99.2	76.9	25.4	13.0	124.6	89.9
3	1	105.1	124.3	39.1	36.9	144.2	161.2
	2	128.3	161.9	57.0	46.7	185.3	208.6
	3	148.7	130.4	47.2	31.9	195.9	162.3
	4	106.4	94.1	11.2	5.6	117.6	99.7
4	1	124.3	170.8	29.7	22.4	154.0	193.2
	2	84.8	131.3	46.1	74.0	130.9	205.3
	3	84.6	124.8	10.2	8.4	94.8	133.2
	4	76.6	106.1	2.9	1.2	79.5	107.3
5	1	78.7	148.5	9.9	17.6	88.6	166.1
	2	71.8	141.7	89.2	150.0	161.0	291.6
	3	91.9	181.0	39.1	50.6	131.0	231.6
	4	91.6	159.5	17.4	19.1	109.0	178.6
6	1	76.4	139.1	46.7	63.8	123.1	202.9
	2	89.1	147.4	13.2	17.1	102.3	164.5
	3	90.7	162.0	44.3	81.5	135.0	243.5
	4	84.1	158.3	24.4	31.9	108.5	190.2
7	1	97.0	143.6	76.4	128.4	173.4	272.0
	2	93.0	169.4	24.2	31.9	117.2	201.3
	3	89.8	171.5	50.5	69.6	136.3	241.1
	4	107.5	197.7	17.4	26.9	124.9	224.6
8	1	79.2	171.6	42.9	50.6	122.1	222.2
	2	78.0	156.0	18.2	35.4	96.2	191.4
	3	75.9	166.1	19.8	37.4	95.7	203.5
	4	57.6	118.8	19.8	36.0	77.4	154.8
9	1	73.8	126.9	25.9	47.0	99.7	173.9
	2	88.5	162.5	82.5	150.0	171.0	312.5
	3	90.5	170.6	19.8	20.8	110.3	191.4
	4	96.8	194.2	46.8	74.3	143.6	268.4
10	1	79.5	163.8	74.7	147.9	154.2	311.6
	2	78.4	162.4	21.3	36.4	99.7	198.8
	3	76.4	164.6	19.6	33.3	98.0	198.0
	4	92.8	155.6	29.1	53.6	121.9	209.1
11	1	69.9	149.5	41.9	57.0	116.8	206.5
	2	84.2	174.9	40.3	62.7	124.5	237.7
	3	81.1	154.0	12.8	20.9	93.9	174.9
	4	92.6	162.2	49.4	69.6	142.0	231.8
12	1	75.9	137.6	10.9	25.0	86.8	162.8
	2	76.3	126.2	12.5	20.6	88.8	146.9
	3	64.8	130.7	28.1	25.9	92.9	156.6
	4	94.9	198.8	65.8	83.7	160.7	282.5

4.6. Effect of time of harvest on the dry matter yield of terminal, lateral and total capsules and seed from the N1P1 non-sprayed treatment (g/m^2).

(Data on which Tables 33 to 38 are based)

Harvest No.	Replication	Term. Caps	Caps. Seed	Lat. Caps	Caps. Seed	Total Caps. Caps	Total Caps. Seed
1	1	98.3	34.3	30.7	2.6	129.0	36.9
	2	107.1	36.4	36.4	5.2	143.5	41.6
	3	66.7	27.6	19.8	0	86.5	27.6
	4	97.9	49.5	25.9	1.7	123.8	51.2
2	1	137.8	71.7	80.6	30.8	218.4	102.5
	2	130.1	81.1	87.7	29.6	217.8	110.7
	3	118.6	87.3	36.6	11.8	155.2	99.1
	4	128.5	86.4	110.7	36.7	239.2	123.1
3	1	80.3	86.8	25.9	14.4	106.2	101.2
	2	112.3	117.5	50.8	16.0	163.1	133.5
	3	98.4	99.5	34.7	5.6	133.1	105.1
	4	127.2	126.1	57.8	42.9	185.0	169.1
4	1	97.0	153.6	93.6	63.8	190.6	217.4
	2	78.2	95.5	28.3	14.9	106.5	110.4
	3	110.8	168.0	88.5	79.0	199.3	247.0
	4	102.1	187.6	65.5	56.1	167.6	243.7
5	1	83.5	141.6	72.5	73.0	156.0	214.6
	2	75.8	105.5	39.8	19.6	115.6	125.1
	3	86.9	159.5	40.7	34.7	127.6	194.2
	4	112.8	146.2	24.4	27.7	137.2	173.9
6	1	58.6	91.8	50.6	83.2	109.2	175.0
	2	89.8	43.0	57.6	93.3	147.4	136.3
	3	103.8	163.6	59.2	39.4	163.0	203.0
	4	87.9	159.1	33.8	13.0	121.7	172.1
7	1	75.2	130.5	41.9	58.5	117.1	189.0
	2	77.7	138.9	45.5	56.1	123.2	195.0
	3	94.6	160.4	59.8	42.7	154.4	203.1
	4	89.6	103.5	72.9	89.1	162.5	192.6
8	1	70.5	138.2	47.5	74.3	118.0	212.4
	2	77.4	121.5	47.0	82.8	124.4	204.3
	3	85.2	144.8	92.3	115.3	177.5	260.1
	4	61.7	137.8	21.0	38.6	82.7	176.4
9	1	76.8	109.4	43.2	84.5	120.0	193.9
	2	69.3	115.9	12.6	14.7	81.9	130.6
	3	75.2	145.7	42.3	60.2	117.5	205.9
	4	76.7	105.3	65.3	47.5	142.0	152.8
10	1	83.5	111.0	38.0	37.5	121.5	148.5
	2	66.3	124.1	60.5	93.8	126.8	217.9
	3	80.1	146.6	39.5	42.6	119.6	189.3
	4	72.5	123.8	11.5	12.5	84.0	136.3
11	1	62.0	121.2	43.2	66.0	105.2	187.2
	2	65.1	125.6	46.6	58.8	111.7	184.4
	3	74.3	116.1	54.9	48.6	129.2	164.7
	4	83.2	98.7	65.8	55.0	149.0	153.7
12	1	57.4	79.9	39.9	53.1	97.4	133.0
	2	60.6	95.5	26.2	51.6	86.9	147.1
	3	74.4	134.2	58.5	86.9	132.9	221.0
	4	67.9	119.5	24.9	25.4	92.9	144.9

4.7. Effect of time of harvest on the fresh and dry matter yields (g/m^2) of stem and leaves and total plant and on fresh head yield (g/m^2) and numbers of capsules/m^2 from the N0 P0 non-sprayed treatment. (Data on which Tables 32, 39 and 40 are based)

Harvest No.	Replication	Stem & Leaves		Total Plant		Head	No. of Caps/m^2
		Fresh	Dry	Fresh	Dry	Fresh	
1	1	5278.0	624.0	6250.4	744.6	972.4	67.6
	2	4978.1	616.4	5882.6	739.7	904.5	87.1
	3	3796.2	501.6	4480.2	595.1	684.0	74.1
	4	6052.8	759.2	7108.4	859.1	1055.6	67.6
2	1	4479.3	623.7	5657.4	861.8	1178.1	81.9
	2	3763.7	542.9	4959.3	770.4	1195.6	85.4
	3	3010.2	417.6	3799.0	562.6	788.8	63.8
	4	3014.9	448.4	3864.5	615.4	849.6	59.0
3	1	2392.3	394.8	3120.8	573.4	728.5	47.0
	2	3304.6	564.2	4488.8	843.2	1184.2	74.4
	3	2921.9	555.1	3952.8	823.5	1050.9	79.3
	4	4068.0	732.0	5448.0	1086.0	1380.0	90.0
4	1	3711.1	601.8	4790.8	920.4	1079.7	70.8
	2	2548.0	392.0	3404.8	621.6	856.8	56.0
	3	2424.9	401.2	3168.3	607.7	743.4	64.9
	4	2616.3	421.8	3568.2	689.7	951.9	74.1
5	1	2142.0	516.6	2860.2	825.3	718.2	81.9
	2	1825.6	554.4	2587.2	918.4	761.6	89.6
	3	1145.7	359.1	1613.1	615.4	467.4	79.8
	4	1397.4	474.3	1953.3	785.4	555.9	71.4
6	1	1944.0	531.6	2319.8	829.8	375.6	78.0
	2	1187.2	475.4	1524.3	754.3	337.1	78.1
	3	896.8	350.5	1193.0	576.5	296.2	70.8
	4	660.0	377.3	975.2	621.5	315.2	71.5
7	1	1341.3	520.2	1705.9	809.8	364.6	96.9
	2	1372.0	610.4	1765.6	950.3	393.6	78.4
	3	1162.3	413.0	1500.8	700.8	338.5	82.6
	4	869.0	407.0	1205.0	693.5	336.0	77.0
8	1	817.6	649.6	1411.2	1187.2	593.6	112.0
	2	523.8	496.6	977.4	907.2	453.6	108.0
	3	548.8	425.6	907.2	733.6	358.4	89.6
	4	603.2	468.0	1014.0	837.2	410.8	88.4
9	1	488.0	408.7	841.8	725.9	353.8	79.3
	2	462.8	405.6	811.2	717.6	348.4	88.4
	3	418.7	371.0	747.3	667.8	328.6	68.9
	4	501.6	410.4	855.0	735.3	353.4	68.4
10	1	625.0	530.0	1030.0	895.0	405.0	75.0
	2	531.0	445.5	922.5	805.5	391.5	63.0
	3	678.3	598.5	1060.2	946.2	381.9	79.8
	4	498.4	425.6	856.8	756.0	358.4	72.8
11	1	638.0	519.2	1056.4	880.0	418.4	92.4
	2	480.2	392.0	835.5	700.7	355.3	58.8
	3	546.0	452.4	901.7	764.4	355.7	83.2
	4	614.8	508.8	1054.2	890.4	439.3	106.4
12	1	537.6	484.8	910.6	798.0	373.0	81.6
	2	385.0	357.5	672.7	616.0	287.7	56.0
	3	424.0	386.9	755.8	689.0	331.8	74.2
	4	331.2	303.6	600.8	544.6	269.6	64.4

4.8. Effect of time of harvest on the fresh and dry matter yields (g/m²) of stem and leaves and total plant and on fresh head yield (g/m²) and numbers of capsules/m² from the N1P0 non-sprayed treatment.
(Data on which Tables 32,39 and 40 are based)

Harvest No.	Replication	Stem & Leaves Fresh	Stem & Leaves Dry	Total Plant Fresh	Total Plant Dry	Head Fresh	No. of Caps/m²
1	1	5256.9	601.8	6124.2	716.9	867.3	70.8
	2	6200.0	868.0	7328.4	1026.8	1128.4	86.8
	3	5588.1	667.8	6369.3	767.3	781.2	63.0
	4	7009.2	792.0	8157.6	943.8	1148.4	85.8
2	1	5244.0	775.2	6441.0	1010.0	1197.0	91.2
	2	4660.2	691.2	5859.0	914.8	1198.8	75.6
	3	4235.1	592.8	5437.8	820.8	1202.7	74.1
	4	3847.8	593.6	5008.5	835.8	1160.7	90.1
3	1	3648.0	636.0	4788.0	888.0	1140.0	96.0
	2	4260.0	744.0	5814.0	1116.0	1554.0	108.0
	3	4292.1	786.6	5631.6	1100.1	1339.5	96.9
	4	4659.2	863.2	6297.2	1258.4	1638.0	104.0
4	1	2552.0	464.0	3311.8	701.8	759.8	81.2
	2	2014.2	410.4	2781.0	637.2	766.8	75.6
	3	3748.5	567.0	4918.5	868.5	1170.0	81.0
	4	2180.5	362.6	3062.5	568.4	882.0	58.8
5	1	1852.2	540.0	2484.0	864.0	631.8	81.0
	2	1847.3	558.6	2420.6	852.6	573.3	78.4
	3	2236.0	613.6	3036.8	920.4	800.8	88.4
	4	1411.1	380.0	1846.1	620.0	435.0	75.0
6	1	967.6	471.5	1306.3	755.3	338.7	73.8
	2	1372.0	563.0	1851.2	894.8	479.2	83.3
	3	1006.5	412.0	1366.8	685.4	360.3	82.5
	4	906.3	466.3	1238.6	727.4	332.3	79.8
7	1	1044.0	588.0	1468.2	956.4	424.2	102.0
	2	1134.0	507.6	1462.2	785.6	328.2	86.4
	3	1024.8	425.6	1285.2	649.5	260.4	72.9
	4	800.8	431.2	1122.8	712.8	322.0	67.2
8	1	565.8	368.0	837.2	611.8	271.4	59.8
	2	712.4	478.4	1123.2	852.8	410.8	88.4
	3	921.1	463.6	1299.3	799.1	378.2	79.4
	4	407.2	291.2	655.2	438.6	208.0	57.2
9	1	480.6	421.2	847.8	756.0	367.2	81.0
	2	508.2	453.6	852.6	764.4	344.4	79.8
	3	441.6	386.4	768.2	676.2	326.6	69.0
	4	537.6	422.4	820.8	676.8	283.2	57.6
10	1	520.8	464.8	884.8	795.2	364.0	100.8
	2	421.2	374.4	738.4	665.6	317.2	67.6
	3	445.2	392.2	757.9	667.8	312.7	63.6
	4	407.0	357.5	674.9	601.8	267.9	60.5
11	1	400.5	333.0	679.5	571.5	279.0	67.5
	2	603.0	495.0	976.1	819.0	373.1	94.5
	3	632.1	519.4	1060.9	886.9	428.8	98.0
	4	585.0	486.0	958.1	805.5	373.1	90.0
12	1	428.4	467.7	747.7	754.3	319.3	76.5
	2	377.3	451.8	680.6	721.3	303.3	68.6
	3	372.6	420.4	673.5	694.1	300.9	78.2
	4	390.0	354.9	678.6	612.3	288.6	70.2

4.9. Effect of time of harvest on the fresh and dry matter yields (g/m^2) of stem and leaves and total plant and on fresh head yield (g/m^2) and numbers of capsules/m^2 from the 10 P1 non-sprayed treatments. (Data on which Tables 32, 39 and 40 are based)

Harvest No.	Replication	Stem & Leaves		Total Plant		Head	No. of Caps/m^2
		Fresh	Dry	Fresh	Dry	Fresh	
1	1	7649.2	873.6	8954.4	1053.5	1305.2	93.6
	2	4428.0	567.0	5259.6	685.6	831.6	75.6
	3	5857.6	744.8	7078.4	911.6	1220.8	95.2
	4	4002.0	522.0	4854.6	644.3	852.6	87.0
2	1	5856.1	837.8	7209.8	1134.0	1351.7	106.2
	2	4414.8	681.2	5813.6	950.0	1399.8	93.6
	3	3463.3	489.7	4454.5	683.8	991.2	70.8
	4	3937.0	570.4	5074.7	784.9	1137.7	80.6
3	1	4004.0	605.0	5324.0	907.5	1320.0	93.5
	2	4463.1	741.0	6121.8	1140.0	1658.7	108.3
	3	4088.7	684.4	5522.4	1044.3	1433.7	88.5
	4	2671.2	448.0	3539.2	660.8	868.0	67.2
4	1	4480.0	694.4	5768.0	1047.2	1288.0	84.0
	2	3405.5	563.5	4591.3	901.6	1185.8	83.2
	3	2154.0	450.0	2736.0	678.0	642.0	73.0
	4	1676.2	290.0	2267.8	481.4	591.6	63.8
5	1	1254.0	451.0	1677.5	704.0	423.5	71.5
	2	1628.4	685.0	2405.8	1135.8	777.4	115.0
	3	2024.0	765.0	2788.5	1028.0	764.5	104.5
	4	1235.4	429.0	1741.6	719.0	516.2	75.4
6	1	1234.0	526.7	1706.0	852.7	452.0	102.6
	2	1111.0	529.1	1477.9	795.9	366.9	137.5
	3	1458.0	526.0	1999.1	904.5	541.1	97.8
	4	951.2	469.2	1317.8	767.9	366.6	92.8
7	1	1396.5	833.0	1918.3	1278.3	521.8	107.8
	2	1078.0	495.0	1456.3	813.4	378.3	93.5
	3	1470.0	617.4	1908.0	994.6	438.0	102.9
	4	996.8	537.6	1399.4	886.9	402.6	72.8
8	1	605.0	489.5	990.0	830.5	385.0	104.5
	2	483.6	468.0	800.8	759.2	317.2	72.8
	3	374.0	363.0	715.0	665.5	341.0	82.5
	4	270.0	252.0	540.0	486.0	270.0	78.0
9	1	531.1	460.6	831.9	733.2	300.8	65.8
	2	795.0	590.0	1330.0	1075.0	535.0	115.0
	3	639.6	436.8	977.6	738.4	338.0	124.8
	4	665.5	550.0	1122.0	962.5	456.5	159.5
10	1	689.0	593.6	1197.8	1060.0	508.8	111.3
	2	565.6	481.6	890.4	784.0	324.8	84.0
	3	558.6	470.4	877.1	769.3	318.5	73.5
	4	443.7	392.7	805.8	729.3	362.1	84.7
11	1	662.4	542.8	1036.4	861.1	374.0	105.8
	2	632.4	610.0	1056.2	872.0	423.8	102.0
	3	459.0	377.4	771.1	646.1	312.1	71.4
	4	537.6	411.6	971.6	815.4	433.5	86.4
12	1	457.6	472.7	736.8	727.5	279.2	62.4
	2	480.0	432.0	745.9	667.2	265.9	67.2
	3	432.0	499.5	711.2	747.9	279.2	81.0
	4	582.8	424.4	1074.4	866.2	491.6	94.0

4.10. Effect of time of harvest on the fresh and dry matter yields (g/m^2) of stems and leaves and total plant and on fresh head yield (g/m^2) and numbers of capsules/m^2 from the N1P1 non-sprayed treatment.
(Data on which Tables 32, 39 and 40 are based)

Harvest No.	Replication	Stem + Leaves Fresh	Stem + Leaves Dry	Total Plant Fresh	Total Plant Dry	Head Fresh	No. of Caps /m2
1	1	7196.8	816.4	8361.6	982.3	1164.8	124.8
	2	8210.8	894.4	9495.2	1079.5	1284.4	93.6
	3	5901.8	690.0	6679.2	804.1	777.4	73.6
	4	5263.5	704.0	6297.5	879.0	1034.0	104.5
2	1	6036.8	896.0	7666.4	1216.8	1629.6	128.8
	2	6981.9	989.4	8772.0	1317.7	1790.1	127.5
	3	5675.8	837.8	7032.8	1092.0	1357.0	106.2
	4	7192.8	1058.4	9050.4	1420.7	1857.6	156.6
3	1	3031.2	525.6	3884.4	734.4	852.2	68.4
	2	4319.3	841.3	5607.1	1137.4	1287.8	112.8
	3	2335.8	448.8	3284.4	688.5	948.6	102.0
	4	4966.1	848.0	6455.4	1203.1	1489.3	100.7
4	1	4569.6	806.4	5985.6	1214.4	1416.0	139.2
	2	2812.8	432.0	3499.2	648.0	686.4	81.6
	3	5109.2	837.4	6672.7	1287.9	1563.5	127.2
	4	4377.8	743.4	5805.6	1150.5	1427.8	135.7
5	1	2568.0	720.0	3331.2	1094.4	763.2	124.8
	2	1764.9	646.0	2268.4	884.5	503.5	95.4
	3	1809.5	544.0	2475.0	863.0	665.5	99.0
	4	2068.0	601.0	2585.0	911.2	517.0	70.5
6	1	1353.6	539.5	1716.5	823.6	362.9	70.4
	2	1438.9	674.5	1984.5	1058.2	545.6	101.2
	3	1890.8	759.8	2400.1	1125.8	509.3	127.6
	4	1279.2	532.5	1701.9	826.3	422.7	114.4
7	1	1044.0	486.0	1406.2	792.0	362.2	103.5
	2	1035.0	607.2	1405.2	925.4	370.2	96.6
	3	1470.1	780.8	1893.9	1138.2	423.8	146.4
	4	1404.0	684.0	1826.0	1039.0	422.0	112.5
8	1	507.6	479.4	878.0	809.8	370.4	98.7
	2	617.4	563.5	989.8	896.7	372.4	102.9
	3	765.0	693.6	1259.7	1132.2	494.7	137.7
	4	382.2	361.2	672.0	621.6	289.8	67.2
9	1	672.0	595.2	1022.4	902.4	350.4	86.4
	2	504.0	445.2	743.4	659.4	239.4	63.0
	3	634.5	564.0	991.7	887.4	357.2	98.7
	4	658.8	588.6	988.2	880.2	329.4	135.0
10	1	500.0	445.0	805.0	720.0	305.0	105.0
	2	476.0	414.8	853.4	765.0	377.4	81.6
	3	582.4	520.0	920.4	826.8	338.0	93.6
	4	484.8	484.8	734.4	705.6	249.6	67.2
11	1	672.0	532.0	1013.6	828.0	341.6	92.0
	2	760.2	621.6	1110.0	919.8	349.8	84.0
	3	801.0	670.5	1146.2	967.5	345.2	103.5
	4	799.0	658.0	1153.3	963.5	354.3	103.4
12	1	455.4	299.0	713.5	526.7	258.1	72.6
	2	460.1	390.0	723.7	622.2	263.6	68.8
	3	516.0	394.3	909.4	746.9	393.4	103.2
	4	427.5	407.3	694.1	653.2	266.4	68.8

4.11. Effect of time of harvest on the dry matter yield of terminal, lateral total capsules and seed from the NO F(sprayed treatment (g/m^2)

(Data on which Tables 33 to 38 are based)

Harvest No.	Replic-ation	Term. Caps.		Lat. Caps.		Tot. Caps.	
		Caps.	Seed	Caps.	Seed	Caps.	Seed
1	1	110.7	45.4	17.9	5.1	128.6	50.6
	2	65.7	23.6	0	0	65.7	23.6
	3	97.2	26.2	17.9	2.6	115.1	28.8
	4	87.6	29.0	0	0	87.6	29.0
2	1	141.5	69.0	11.0	0	152.5	69.0
	2	135.6	66.6	19.8	3.0	155.4	69.6
	3	126.3	82.6	56.5	23.6	182.8	106.2
	4	139.2	84.6	60.0	18.0	199.2	102.6
3	1	119.6	111.6	6.2	6.2	125.8	117.8
	2	121.8	107.4	39.0	34.8	160.8	142.2
	3	99.8	99.3	33.8	19.8	133.6	119.1
	4	99.9	91.3	21.6	13.5	121.5	104.8
4	1	130.1	178.7	57.2	86.4	187.3	265.1
	2	99.2	151.4	30.2	26.1	129.4	177.5
	3	98.6	139.2	7.0	12.8	105.6	152.0
	4	114.7	170.8	13.4	6.5	128.1	187.3
5	1	83.2	144.7	21.1	29.2	104.3	173.9
	2	92.1	158.0	48.2	78.1	140.3	236.1
	3	101.5	168.2	63.8	98.6	165.3	266.8
	4	102.7	158.3	38.3	37.7	141.0	196.0
6	1	100.1	184.2	6.6	13.2	106.7	197.4
	2	103.3	187.6	34.8	36.0	138.1	233.6
	3	106.8	187.9	34.8	62.8	141.6	250.7
	4	76.0	137.5	13.5	14.0	89.5	151.5
7	1	117.1	192.0	25.6	39.7	142.7	231.7
	2	85.5	137.9	15.4	18.2	100.9	156.2
	3	105.6	187.6	17.7	23.0	123.3	210.6
	4	77.8	147.4	23.8	36.7	101.6	184.1
8	1	121.5	189.3	1.7	0.6	123.2	189.8
	2	94.1	163.5	32.5	43.7	126.6	207.2
	3	92.4	179.2	26.9	59.4	119.3	238.6
	4	88.7	163.6	8.1	16.8	96.8	180.4
9	1	95.7	188.1	33.6	39.6	129.3	227.7
	2	82.3	141.7	12.4	22.5	94.7	164.2
	3	106.9	189.0	84.2	159.8	191.1	348.8
	4	100.9	178.9	4.7	6.8	105.6	185.6
10	1	87.9	190.8	33.8	72.8	121.7	263.6
	2	98.2	176.3	48.2	92.1	146.4	268.4
	3	93.0	203.5	19.3	33.0	112.3	236.5
	4	94.1	167.4	20.8	36.4	114.9	203.8
11	1	102.1	192.9	24.2	22.4	126.3	215.4
	2	72.8	129.5	35.4	36.4	108.2	165.9
	3	81.3	139.4	20.3	36.4	101.6	175.8
	4	75.6	141.1	30.8	47.6	106.4	188.7
12	1	84.9	181.3	18.2	36.5	103.1	217.7
	2	81.6	174.9	19.4	35.7	101.0	210.6
	3	86.5	119.0	20.0	32.5	106.5	151.5
	4	61.5	116.1	13.3	21.2	74.8	137.3

4.12. Effect of time of harvest on the dry matter yield of terminal, lateral and total capsules and seed from the m1 FO sprayed treatment (g/m²)

(Data on which Tables 33 to 38 are based)

Harvest No.	Replication	Term. Caps.		Lat. Caps.		Tot. Caps.	
		Caps.	Seed	Caps.	Seed	Caps.	Seed
1	1	73.8	19.5	0	0	73.8	19.5
	2	94.6	19.5	10.4	1.2	105.0	20.7
	3	77.9	23.6	11.8	1.2	89.7	24.8
	4	91.4	27.1	4.4	0	95.8	27.1
2	1	118.2	65.5	10.6	7.3	128.8	72.8
	2	130.5	79.3	76.3	45.8	206.8	125.1
	3	128.2	67.3	48.1	16.8	176.3	84.1
	4	114.0	65.5	19.5	6.9	133.5	72.5
3	1	115.6	114.5	42.1	23.2	157.7	137.7
	2	152.3	152.3	27.4	26.9	179.7	179.2
	3	120.4	99.7	0	0	120.4	99.7
	4	108.5	109.6	0	0	108.5	109.6
4	1	118.7	140.0	9.0	3.9	127.7	143.9
	2	118.0	147.6	26.8	24.4	144.8	172.0
	3	127.4	152.2	59.6	56.1	187.0	208.3
	4	102.6	135.0	42.7	40.1	145.3	175.5
5	1	108.6	174.7	13.4	20.2	122.0	194.9
	2	95.6	131.2	41.6	56.7	137.2	187.9
	3	96.6	157.2	40.2	60.0	136.8	217.2
	4	90.1	151.6	55.3	89.5	145.4	241.1
6	1	99.1	161.8	42.0	67.2	141.1	229.0
	2	80.6	108.6	14.3	20.2	94.9	128.9
	3	91.5	146.9	33.0	49.0	124.5	195.9
	4	101.1	161.8	13.0	16.1	114.1	177.9
7	1	97.2	163.1	38.3	55.1	135.5	218.2
	2	95.2	171.0	26.2	34.2	121.4	205.2
	3	112.9	168.4	50.0	79.3	162.9	247.7
	4	102.4	152.9	49.4	78.5	151.8	231.4
8	1	110.2	187.9	53.5	90.7	163.7	278.6
	2	92.2	128.2	10.1	16.3	102.3	144.5
	3	89.0	144.5	29.7	38.1	118.7	182.6
	4	94.1	150.6	56.0	72.8	150.1	223.4
9	1	68.9	166.9	51.7	51.0	120.6	217.9
	2	107.3	199.1	29.7	56.1	137.0	255.2
	3	96.7	167.4	43.2	63.7	139.9	231.1
	4	4.2	140.4	24.4	39.0	108.6	179.4
10	1	96.9	201.0	42.7	58.8	139.6	259.8
	2	86.9	171.1	45.7	50.6	132.6	221.7
	3	89.6	152.3	23.5	38.6	113.1	191.0
	4	109.4	180.1	37.6	74.1	147.0	254.2
11	1	95.1	158.	43.1	68.6	138.2	227.4
	2	76.9	116.8	49.6	84.0	126.5	200.8
	3	74.8	141.9	18.6	36.3	93.4	178.2
	4	105.3	135.5	37.5	42.0	142.8	177.5
12	1	77.1	140.5	36.2	74.7	113.3	215.3
	2	79.9	161.2	35.3	60.3	115.2	221.5
	3	80.1	151.4	39.2	46.2	119.2	197.6
	4	59.3	105.8	46.4	80.4	105.8	186.2

4.13. Effect of time of harvest on the dry matter yield of terminal, lateral and total capsules and seed from the NO P1 sprayed treatment (g/m^2)

(Data on which Tables 33 to 38 are based)

Harvest No.	Replication	Term. Caps		Lat. Caps		Tot. Caps.	
		Caps.	Seed	Caps.	Seed	Caps.	Seed
1	1	97.2	33.0	12.0	1.2	109.2	34.2
	2	88.2	31.3	23.8	5.2	112.0	36.5
	3	84.1	21.5	11.6	1.2	95.7	22.6
	4	90.2	23.0	12.3	0	102.5	23.0
2	1	107.0	80.6	86.2	28.6	193.2	109.2
	2	133.8	105.0	34.2	12.0	168.0	117.0
	3	123.9	82.6	13.0	1.8	136.9	84.4
	4	107.5	96.9	56.0	34.2	163.5	131.0
3	1	126.5	195.9	78.7	85.6	205.2	281.5
	2	138.5	106.0	73.5	43.3	212.0	149.3
	3	133.0	133.0	24.4	6.7	157.4	139.7
	4	138.6	90.6	21.0	12.6	159.6	103.2
4	1	131.1	133.4	38.3	34.8	169.4	168.2
	2	97.4	135.0	81.8	104.2	179.2	239.1
	3	103.0	146.9	74.3	60.0	177.3	206.8
	4	114.1	187.9	61.6	84.2	175.7	272.1
5	1	87.6	156.0	82.2	121.2	169.8	277.2
	2	112.8	187.8	18.0	33.6	130.8	221.4
	3	92.7	161.0	31.1	39.7	123.8	200.7
	4	110.8	185.0	62.0	85.3	172.8	270.3
6	1	97.9	177.1	37.4	61.6	135.3	238.7
	2	90.7	158.5	9.5	17.9	100.2	176.4
	3	82.1	164.2	43.2	76.8	125.3	241.0
	4	87.0	168.2	13.3	20.3	100.3	188.5
7	1	103.0	162.2	50.5	69.4	153.5	231.5
	2	78.8	119.9	27.5	40.5	106.3	160.4
	3	94.6	178.1	49.5	79.0	143.9	257.0
	4	99.8	164.7	26.1	17.4	125.9	182.1
8	1	96.3	186.5	50.4	74.5	146.7	261.0
	2	87.5	163.9	40.7	72.1	128.2	236.0
	3	74.7	162.5	3.4	0	78.1	162.5
	4	87.3	168.2	22.4	34.2	109.7	202.4
9	1	68.4	154.3	30.0	47.5	98.4	201.8
	2	89.1	160.6	43.5	81.4	132.6	242.0
	3	73.1	141.4	21.7	31.5	94.7	172.7
	4	88.4	171.0	29.1	38.8	117.5	209.8
10	1	79.9	161.5	39.4	64.8	119.3	226.3
	2	104.9	206.2	35.4	61.6	146.3	267.8
	3	103.2	215.4	19.7	36.0	122.9	251.4
	4	95.7	163.9	7.2	17.1	102.9	181.0
11	1	96.4	148.4	45.9	61.2	142.3	209.6
	2	86.3	166.9	42.6	40.6	128.9	207.5
	3	93.0	168.0	49.3	94.6	142.3	262.6
	4	78.1	139.2	10.5	12.1	88.6	151.3
12	1	66.6	130.1	34.7	64.4	101.3	194.4
	2	79.9	173.9	27.5	37.8	107.4	211.7
	3	87.5	161.5	35.2	38.9	122.7	204.1
	4	59.2	121.8	0	0	59.2	121.8

4.14. Effect of time of harvest on the dry matter yield of terminal, lateral and total capsules and seed from the N1P1 sprayed treatment (g/m^2).

(Data on which Tables 33 to 38 are based)

Harvest	Replication	Term. Caps.		Lat. Caps.		Tot. Caps.	
		Caps.	Seed.	Caps.	Seed	Caps.	Seed
1	1	107.0	45.0	29.5	9.0	136.5	54.0
	2	116.6	52.4	10.8	1.1	127.4	53.5
	3	96.9	42.3	18.0	3.5	114.9	45.8
	4	109.8	36.4	29.1	6.2	138.9	42.6
2	1	123.8	84.0	63.3	28.0	187.0	112.0
	2	125.3	103.8	40.6	6.4	165.9	110.2
	3	140.8	103.0	74.9	30.7	215.7	133.7
	4	117.6	96.3	39.2	13.4	156.8	109.7
3	1	114.2	163.5	73.4	54.9	187.6	218.4
	2	107.3	92.6	117.6	76.0	224.9	168.6
	3	127.5	111.2	61.7	29.5	189.2	140.7
	4	124.3	103.6	107.5	49.8	231.8	153.4
4	1	111.2	136.8	86.1	46.7	197.3	183.5
	2	98.4	146.9	41.3	39.8	139.7	186.7
	3	98.9	145.9	59.7	39.8	158.6	185.7
	4	98.0	141.4	58.7	27.4	156.7	168.8
5	1	87.2	145.9	61.2	58.1	148.4	204.0
	2	112.2	189.8	69.9	78.1	182.1	267.9
	3	81.4	148.5	15.4	17.1	96.8	165.6
	4	89.3	167.3	85.2	86.7	174.5	254.0
6	1	90.2	153.9	77.8	111.8	168.0	265.7
	2	105.8	211.1	93.4	140.9	199.0	352.0
	3	83.7	155.0	56.2	62.4	139.9	217.4
	4	78.4	147.3	30.2	27.6	108.6	174.9
7	1	73.4	112.3	66.7	100.8	140.1	213.1
	2	80.4	133.3	50.0	74.5	130.4	207.8
	3	96.3	168.0	74.5	125.4	170.8	293.4
	4	77.9	124.0	55.4	36.8	133.3	160.8
8	1	73.0	110.4	79.7	97.4	152.7	207.4
	2	118.8	124.2	65.3	86.9	184.1	211.1
	3	82.2	132.0	47.2	62.5	129.4	194.5
	4	79.4	151.3	53.6	61.1	133.0	212.4
9	1	67.2	130.2	79.4	105.0	146.6	235.2
	2	91.2	145.2	60.2	60.2	151.4	205.4
	3	74.5	141.1	47.2	65.5	121.7	206.6
	4	89.5	132.5	89.7	96.6	170.2	229.1
10	1	83.7	145.2	43.5	58.3	127.2	203.5
	2	82.8	181.8	108.8	149.9	191.6	331.7
	3	94.3	169.6	59.9	84.8	154.2	254.4
	4	102.3	206.3	42.9	61.1	145.2	267.3
11	1	79.2	153.0	68.9	67.5	148.1	220.5
	2	62.0	95.2	83.6	92.0	145.6	187.2
	3	82.8	164.2	32.8	41.7	115.6	205.8
	4	75.0	111.3	39.0	27.6	114.0	138.9
12	1	71.5	112.2	42.1	67.6	113.7	179.8
	2	90.0	141.4	104.0	160.2	194.0	301.6
	3	78.5	143.8	34.7	30.1	113.2	173.9
	4	82.3	150.9	55.9	80.9	138.2	231.8

4.15. Effect of time of harvest on the fresh and dry matter yields (g/m^2) of stem and leaves and total plant and on fresh head yield (g/m^2) and numbers of capsules/m^2 from the N0 P0 sprayed treatment.

(Data on which Tables 32, 39, 40 are based)

Harvest No.	Replic-- ation	Stem & Leaves		Total Plant		Head	No. of
		Fresh	Dry	Fresh	Dry	Fresh g/m2	Caps./m2
1	1	6284.8	729.6	7558.4	908.8	1273.6	83.2
	2	3720.0	458.8	4402.0	548.1	682.0	62.0
	3	4812.8	627.2	5817.6	771.1	1004.8	76.8
	4	4437.0	591.6	5266.4	708.2	829.4	58.0
2	1	4616.8	655.4	5817.4	876.9	1200.6	69.6
	2	4482.0	660.0	5742.0	885.0	1260.0	72.0
	3	5197.9	778.8	6726.0	1067.9	1528.1	88.5
	4	5760.0	858.0	7380.0	1159.8	1620.0	96.0
3	1	2932.6	483.6	4147.8	725.4	1215.2	68.2
	2	3534.0	564.0	4830.0	870.0	1296.0	90.0
	3	2979.6	499.2	4071.6	754.0	1092.0	83.2
	4	2521.8	410.4	3472.2	637.2	950.4	75.6
4	1	1086.8	766.8	6733.8	1220.4	1647.0	91.8
	2	3404.6	522.0	4570.4	829.4	1165.8	87.0
	3	2552.0	394.4	3433.6	649.6	881.6	63.8
	4	3422.1	524.6	4520.1	841.8	1098.0	73.2
5	1	1501.2	421.2	2019.6	696.6	518.4	81.0
	2	2311.9	622.2	3111.0	1000.4	799.1	103.7
	3	2445.3	627.0	3271.8	1060.2	826.5	96.9
	4	2227.2	713.4	3010.2	1049.8	783.0	92.8
6	1	1894.0	556.5	2270.0	860.6	376.0	56.4
	2	1333.4	538.1	1786.6	909.8	453.2	94.4
	3	1512.8	575.2	1995.4	967.5	482.6	85.4
	4	855.0	339.0	1162.0	580.0	307.0	65.0
7	1	1459.2	576.0	1889.9	950.3	430.7	89.6
	2	917.7	410.4	1237.9	677.3	320.2	79.8
	3	1150.5	507.4	1537.4	841.3	386.9	76.7
	4	923.4	442.8	1249.4	728.4	326.0	81.0
8	1	1176.0	504.0	1523.2	817.6	347.2	61.6
	2	828.8	504.0	1220.8	840.0	392.0	89.6
	3	588.0	442.4	996.8	806.4	408.8	84.0
	4	719.2	394.4	1032.4	667.0	313.2	63.8
9	1	770.0	495.0	1166.0	852.5	396.0	99.0
	2	496.8	340.4	786.6	602.6	289.8	55.2
	3	1123.2	750.6	1722.6	1290.6	599.4	118.8
	4	452.4	400.4	780.0	691.6	327.6	57.2
10	1	598.0	520.0	1024.4	904.8	426.4	83.2
	2	579.5	512.4	1030.9	927.2	451.4	97.6
	3	495.0	440.0	880.0	792.0	385.0	82.5
	4	410.8	364.0	759.2	681.2	348.4	72.8
11	1	531.0	436.6	926.9	778.3	395.9	94.4
	2	514.8	426.4	834.1	700.5	319.3	88.4
	3	478.4	395.2	802.3	672.4	323.9	78.0
	4	476.0	397.6	815.9	692.7	339.9	89.6
12	1	547.2	481.1	902.9	800.3	355.7	79.8
	2	438.6	462.6	787.5	773.7	348.9	71.4
	3	365.0	459.0	652.0	719.0	287.0	65.0
	4	275.6	489.2	513.0	701.7	237.4	74.2

4.16. Effect of time of harvest on the fresh and dry matter yields (g/m^2) of stem and leaves and total plant and on fresh head yield and numbers of capsules/m^2 from the N1 P0 sprayed treatment

(Data on which Tables 32, 39, 40 are based)

Harvest No.	Replication	Stem & Leaves Fresh	Stem & Leaves Dry	Total Plant Fresh	Total Plant Dry	Head Fresh g/m^2	No. of Caps./m^2
1	1	5345.4	542.8	6059.3	636.1	713.9	59.0
	2	5947.5	683.2	6923.5	808.9	976.0	73.2
	3	5846.9	649.0	6714.2	763.5	867.3	88.5
	4	3956.4	478.8	4743.9	601.7	787.5	75.6
2	1	4138.4	599.2	5224.8	800.8	1086.4	72.8
	2	6441.6	927.2	8222.8	1258.9	1781.2	122.0
	3	3764.2	626.4	4941.6	886.8	1177.4	87.0
	4	4032.0	592.2	5118.7	798.2	1086.7	75.6
3	1	4023.0	658.8	5302.8	955.8	1279.8	97.2
	2	5353.6	862.4	6826.4	1220.8	1472.8	78.4
	3	3274.5	542.8	4189.0	761.1	914.5	59.0
	4	2871.0	464.0	3729.4	684.4	858.4	58.0
4	1	3752.8	560.0	4564.0	834.4	991.2	67.2
	2	3751.5	597.8	4922.7	914.6	1171.2	85.4
	3	4566.6	743.4	6088.8	1138.7	1522.2	106.2
	4	3672.0	583.2	4843.8	907.2	1171.8	86.4
5	1	2156.0	537.6	2816.8	856.8	660.8	67.2
	2	2775.6	648.0	3542.4	972.0	766.8	81.0
	3	2028.0	588.0	2766.0	942.0	738.0	90.0
	4	2052.0	638.4	2850.0	1026.0	798.0	108.3
6	1	2128.0	720.2	2647.7	1090.3	519.7	89.6
	2	1911.0	537.2	2269.7	761.0	358.7	54.6
	3	1132.8	522.7	1524.6	843.1	391.8	88.5
	4	1264.8	495.4	1621.3	787.4	356.5	74.4
7	1	1209.6	572.4	1617.8	926.0	408.2	86.4
	2	1128.6	558.6	1503.5	885.2	374.9	91.2
	3	1848.3	695.4	2542.3	1105.3	494.0	122.0
	4	1809.6	676.0	2276.0	1059.7	466.4	98.8
8	1	939.6	718.5	1425.6	1161.0	486.0	102.6
	2	763.2	379.2	1046.4	624.0	283.2	57.6
	3	660.8	470.4	1002.4	772.8	341.6	95.2
	4	828.8	481.6	1248.8	856.8	420.0	95.2
9	1	582.4	483.6	956.8	821.6	374.4	93.6
	2	627.0	522.5	1056.0	913.0	429.0	82.5
	3	696.6	550.8	1170.0	923.4	410.4	102.6
	4	520.0	431.6	837.2	722.8	317.2	78.0
10	1	638.4	565.6	1080.8	968.8	442.4	112.0
	2	489.5	440.0	880.0	792.0	390.5	99.0
	3	481.6	425.6	812.0	728.0	330.4	78.4
	4	604.2	530.1	1048.8	934.8	444.6	91.2
11	1	686.0	558.6	1116.7	924.2	430.7	93.1
	2	600.6	487.2	984.0	814.4	383.4	79.8
	3	456.5	385.0	770.1	656.2	313.6	77.0
	4	588.0	492.8	961.0	813.1	373.0	95.2
12	1	484.1	429.1	847.4	757.1	363.3	75.2
	2	485.1	450.3	858.5	783.5	373.4	83.3
	3	435.6	395.6	787.6	712.4	352.0	74.8
	4	365.5	384.4	689.5	683.7	325.8	81.7

4.17. Effect of time of harvest on the fresh and dry matter yields (g/m^2) of stem and leaves and total plant and on fresh head yield and numbers of capsules/m^2 from the N0 P1 sprayed treatment

(Data on which Tables 32, 39, 40 are based)

Harvest No.	Replication	Stem & Leaves		Total Plant		Head	No. of
		Fresh	Dry	Fresh	Dry	Fresh g/m^2	Caps./m^2
1	1	6330.0	714.0	7386.0	857.4	1056.0	84.0
	2	5672.4	661.2	6722.2	809.7	1049.8	98.6
	3	4193.4	568.4	5046.0	686.7	852.6	81.2
	4	3388.0	481.6	4188.8	607.1	800.8	67.2
2	1	5605.6	924.0	7078.4	1226.4	1472.8	123.2
	2	5225.8	708.0	6617.8	993.0	1392.0	96.0
	3	7276.8	649.0	9126.4	870.1	1849.6	70.8
	4	5185.6	711.2	6482.0	1005.7	1296.4	112.0
3	1	5728.8	1227.6	7681.8	1711.2	1953.0	161.2
	2	4674.0	792.3	6252.9	1151.4	1578.9	125.4
	3	3879.6	622.2	5081.3	921.1	1201.7	103.7
	4	3186.0	516.0	4230.0	760.0	1044.0	78.0
4	1	4048.4	707.6	5196.8	1044.0	1148.4	92.8
	2	4737.6	884.8	6070.4	1304.8	1332.8	106.4
	3	5357.0	775.5	6891.5	1160.5	1534.5	115.5
	4	4867.8	768.6	6514.8	1220.0	1647.0	122.0
5	1	3210.0	732.0	4194.0	1176.0	984.0	120.0
	2	2076.0	588.0	2754.0	942.0	678.0	78.0
	3	1671.4	524.0	2324.1	847.3	652.7	97.6
	4	3042.2	757.0	4006.8	1202.2	964.6	95.4
6	1	1633.5	700.7	2107.7	1074.7	474.2	93.5
	2	1204.0	432.9	1559.0	709.5	355.0	67.2
	3	1310.4	591.8	1800.5	958.1	490.1	81.6
	4	1386.2	454.7	1741.7	743.5	355.5	75.4
7	1	1718.7	688.5	2166.9	1073.5	448.2	91.8
	2	1047.6	486.0	1366.1	752.6	318.5	102.6
	3	2156.0	649.6	2669.4	1050.5	513.4	100.8
	4	1653.0	527.8	2045.0	835.7	392.0	87.0
8	1	711.2	604.8	1164.8	1008.0	453.6	72.8
	2	687.5	473.0	1094.5	836.0	407.0	88.0
	3	433.2	364.8	706.8	609.9	273.6	62.7
	4	584.1	389.4	932.2	708.0	348.1	88.5
9	1	562.4	414.2	896.8	714.4	334.4	72.2
	2	720.5	539.0	1133.0	913.0	412.5	99.0
	3	339.0	347.7	695.4	615.6	296.4	74.1
	4	661.2	467.4	1026.0	798.0	364.8	91.2
10	1	621.0	545.4	999.0	891.0	378.0	102.6
	2	701.5	701.5	1152.9	1110.2	451.4	103.7
	3	654.0	576.0	1068.0	948.0	414.0	84.0
	4	544.5	412.5	854.2	696.4	309.7	71.5
11	1	780.3	642.6	1202.6	994.5	422.3	96.9
	2	655.2	530.4	1055.1	868.4	399.9	104.0
	3	621.6	504.0	1097.0	912.8	475.4	106.4
	4	451.0	363.0	728.2	602.9	277.2	71.5
12	1	522.0	407.3	852.8	659.3	330.8	76.5
	2	464.4	496.3	814.9	809.5	350.5	81.0
	3	577.5	497.8	944.4	822.3	366.9	93.5
	4	290.0	533.6	490.1	713.4	200.1	58.0

4.18. Effect of time of harvest on the fresh and dry matter yields (g/m^2) of stem and leaves and total plant and on fresh head yield and number of capsules/m^2 from the N1-1 sprayed treatment.

(Data on which Tables 32, 39, 40 are based).

Harvest	Replication	Stem + Leaves Fresh	Stem + Leaves Dry	Total Plant Fresh	Total Plant Dry	Head Fresh Wt. /m^2	No. of Caps. /m^2
1	1	9850.0	1115.0	11205.0	1305.5	1355.0	90.0
	2	7867.8	928.8	9028.8	1109.7	1161.0	81.0
	3	5974.0	725.0	6977.4	885.7	1003.4	82.2
	4	7100.8	862.4	8282.4	1043.9	1181.6	106.4
2	1	5605.6	840.0	7078.4	1139.0	1472.8	112.0
	2	5225.8	794.6	6617.8	1070.6	1392.0	127.6
	3	7276.8	1049.6	9126.4	1398.9	1849.6	147.2
	4	5185.6	767.2	6482.0	1033.7	1296.4	112.0
3	1	4883.2	817.6	6501.6	1226.4	1618.4	123.3
	2	5762.4	1283.8	7501.9	1675.8	1739.5	142.1
	3	3723.0	754.8	5028.6	1086.3	1305.6	107.1
	4	5659.2	1232.0	7420.0	1612.8	1724.8	140.0
4	1	5648.7	906.3	7153.5	1288.2	1504.8	136.8
	2	3733.2	617.1	4875.6	943.5	1142.4	96.4
	3	4319.7	703.8	5589.6	1047.5	1269.9	117.3
	4	4098.3	735.3	5152.8	1065.9	1054.5	119.7
5	1	2794.8	714.0	3508.8	1065.9	714.0	112.2
	2	3432.0	880.0	4433.0	1331.0	1001.0	126.5
	3	2238.5	561.0	2777.5	825.0	539.0	77.0
	4	2539.8	724.0	3457.8	1147.3	918.0	127.5
6	1	1620.0	790.0	2160.0	1223.6	540.0	124.2
	2	2646.0	971.5	3404.7	1522.9	758.7	145.8
	3	1820.0	691.6	2351.9	1048.9	531.9	114.4
	4	1303.8	505.6	1700.2	789.2	396.4	84.8
7	1	1488.0	628.8	1898.8	982.0	410.8	105.6
	2	1435.7	617.4	1827.7	955.5	392.0	107.8
	3	1551.2	772.8	2104.4	1237.0	553.2	134.4
	4	1450.4	597.8	1808.0	891.7	357.6	116.4
8	1	595.2	508.8	998.4	868.8	403.2	134.4
	2	1317.6	691.2	1760.4	1085.4	442.8	113.4
	3	954.0	551.2	1314.4	879.8	360.4	106.0
	4	747.3	564.0	1132.7	907.1	385.4	112.8
9	1	730.8	646.8	1155.0	1029.0	424.2	130.2
	2	733.2	639.2	1128.0	996.4	394.8	108.1
	3	597.6	532.8	961.2	860.4	363.6	75.6
	4	759.0	680.8	1200.6	1081.0	441.6	138.0
10	1	646.6	572.4	1007.0	901.0	360.4	95.4
	2	886.9	784.0	1465.1	1308.3	578.2	147.0
	3	768.5	678.4	1219.0	1086.5	450.5	121.9
	4	775.5	682.0	1232.0	1100.0	456.5	115.5
11	1	679.5	549.0	1112.4	917.6	432.9	117.0
	2	636.0	512.0	1034.0	844.8	398.0	128.0
	3	695.8	578.2	1067.2	894.7	371.4	83.3
	4	630.2	506.0	928.3	759.0	298.1	87.4
12	1	362.6	456.7	688.0	755.6	325.4	98.0
	2	764.4	470.6	1317.7	964.6	553.3	135.2
	3	540.6	466.7	860.9	753.3	320.3	86.7
	4	612.5	443.0	1023.6	820.3	411.1	112.7

4.19. Analysis of Variance - Effect of time of harvest, fungicidal sprays and NP fertiliser on dry matter yield of terminal capsules (g/m^2)

Source of Var.	DF	SS	MS	VR
Block	3	219.6	73.2	0.486
Spray	1	4182.4	4182.4	18.780
P	1	1169.4	1169.4	5.251
N	1	495.7	495.7	2.226
Spray X P	1	0.9	0.9	0.004
Spray X N	1	129.6	129.6	0.582
P X N	1	100.8	100.8	0.452
Spray X P X N	1	16.4	16.4	0.074
Error (1)	21	4676.9	222.7	1.478
Time	11	73081.2	6643.7	44.097
Time X Spray	11	1882.7	171.2	1.136
Time X P	11	2924.5	265.9	1.765
Time X N	11	2105.3	191.4	1.270
Time X Spray X P	11	3032.3	275.7	1.830
Time X Spray X N	11	1627.9	148.0	0.982
Time X P X N	11	1849.9	168.2	1.116
Error (2)	275	41432.1	150.7	
Total	383	138927.4		

4.20. Analysis of Variance - Effect of time of harvest, fungicidal sprays and NP fertiliser on dry matter yield of lateral capsules (g/m^2)

Source of Var.	DF	SS	MS	VR
Block	3	2629.4	943.1	2.706
Spray	1	3714.5	3714.5	9.545
P	1	32360.2	32360.2	83.157
N	1	15840.2	15840.2	40.705
Spray X P	1	71.0	71.0	0.182
Spray X N	1	447.9	447.9	1.151
P X N	1	4669.8	4669.8	12.000
Spray X P X N	1	332.1	332.1	0.853
Error (1)	21	8172.1	389.1	1.116
Time	11	17591.2	1599.2	4.586
Time X Spray	11	3053.2	277.6	0.796
Time X P	11	4142.9	376.6	1.080
Time X N	11	3043.4	276.7	0.794
Time X Spray X P	11	5331.0	484.6	1.390
Time X Spray X N	11	7610.1	691.8	1.985
Time X P X N	11	1503.8	136.7	0.392
Error (2)	275	95857.2	348.6	
Total	383	206569.8		

4.21. Analysis of Variance - Effect of time of harvest, fungicidal sprays and NP fertiliser on dry matter yield of total capsules (g/m^2)

Source of Var.	DF	SS	MS	VR
Block	3	4478.3	1492.8	2.569
Spray	1	15790.1	15790.1	24.649
P	1	21238.5	21238.5	33.154
N	1	10742.1	10742.1	16.769
Spray X P	1	86.8	86.8	0.136
Spray X N	1	1055.4	1055.4	1.647
P X N	1	3391.5	3391.5	5.294
Spray X P X N	1	202.4	202.4	0.316
Error (1)	21	13452.7	640.6	1.103
Time	11	114230.0	10384.5	17.875
Time X Spray	11	7014.3	637.7	1.098
Time X P	11	8295.4	754.1	1.298
Time X N	11	3104.5	282.2	0.486
Time X Spray X P	11	13496.3	1226.9	2.112
Time X Spray X N	11	11874.9	1079.5	1.858
Time X P X N	11	4859.9	441.8	0.760
Error (2)	275	159766.3	581.0	
Total	383	393079.5		

4.22. Analysis of Variance - Effect of time of harvest, fungicidal sprays and NP fertiliser on dry matter yield of seed from terminal capsules (g/m^2)

Source	DF	SS	MS	VR
Block	3	939.2	313.1	0.763
Spray	1	7293.2	7293.2	10.559
P	1	940.3	940.3	1.361
N	1	19844.7	19844.7	28.730
Spray X P	1	886.6	886.6	1.284
Spray X N	1	1738.7	1738.7	2.517
P X N	1	691.5	691.5	1.001
Spray X P X N	1	189.7	189.7	0.275
Error (1)	21	14508.3	690.7	1.683
Time	11	560007.0	50909.7	124.033
Time X Spray	11	5752.7	523.0	1.274
Time X P	11	11711.1	1064.6	2.594
Time X N	11	11107.2	1009.7	2.460
Time X Spray X P	11	5312.2	482.9	1.177
Time X Spray X N	11	2174.5	197.7	0.482
Time X P X N	11	5795.0	526.8	1.284
Error(2)	275	112874.9	410.5	
Total	383	761764.0		

4.23. Analysis of Variance - Effect of time of harvest, fungicidal sprays and N P fertiliser on dry matter yield of seed from lateral capsules (g/m^2)

Source of Var.	DF	SS	MS	VR
Block	3	11401.6	3800.5	5.394
Spray	1	6692.5	6692.5	8.645
P	1	20928.8	20928.8	27.035
N	1	5479.0	5479.0	7.078
Spray x P	1	9.8	9.8	0.013
Spray x N	1	2436.5	2936.5	3.793
P x N	1	667.0	667.0	0.862
Spray x P x N	1	394.3	394.3	0.509
Error (1)	21	16256.9	774.1	1.099
Time	11	108004.2	9818.6	13.934
Time x Spray	11	7579.6	689.1	0.978
Time x P	11	7341.3	667.4	0.947
Time x N	11	7900.7	718.2	1.019
Time x Spray x P	11	4387.1	398.8	0.566
Time x Spray x N	11	12565.4	1142.3	1.621
Time x P x N	11	6346	577.0	0.819
Error (2)	275	193775.4	704.8	
Total	383	412666.9		

4.24. Analysis of Variance - Effect of time of harvest, fungicidal sprays and N P fertiliser on dry matter yield of seed from total capsules (g/m^2)

Source of Var.	DF	SS	MS	VR
Block	3	15311	5104	3.931
Spray	1	28032	28032	19.508
P	1	13028	13028	9.066
N	1	4481	4481	3.118
Spray x P	1	712	712	0.496
Spray x N	1	9158	9158	6.373
P x N	1	0	0	0.000
Spray x P x N	1	1120	1120	0.779
Error (1)	21	30177	1437	1.107
Time	11	1133702	103064	79.379
Time x Spray	11	21039	1913	1.473
Time x P	11	13546	1231	0.948
Time x N	11	13113	1192	0.918
Time x Spray x P	11	9624	875	0.674
Time x Spray x N	11	19861	1806	1.391
Time x P x N	11	11417	1038	0.799
Error (2)	275	357055	1298	
Total	383	1681376		

4.25. Analysis of Variance - Effect of time of harvest, fungicidal sprays and N P fertiliser on dry matter yield of stem and leaves (g/m^2)

Source of Var.	DF	SS	MS	VR
Block	3	239892	79964	6.965
Spray	1	307083	307083	18.183
P	1	905836	905836	53.636
N	1	447317	447317	26.487
Spray x P	1	22809	22809	1.351
Spray x N	1	5212	5212	0.309
P x N	1	106004	106004	6.277
Spray x N	1	2029	2029	0.120
Error (1)	21	354658	16888	1.471
Time	11	3130175	284561	24.787
Time x Spray	11	202727	28430	1.605
Time x P	11	202307	18392	1.602
Time x N	11	243552	22141	1.929
Time x Spray x P	11	348603	31691	2.760
Time x Spray x N	11	181484	16499	1.437
Time x P x N	11	115716	10520	0.916
Error (2)	275	3157087	11480	
Total	383	9972492		

4.26. Analysis of Variance - Effect of time of harvest, fungicidal sprays and N P fertiliser on dry matter yield of total plant (g/m^2)

S

Source of Var.	DF	SS	MS	VR
Block	3	452881	150960	6.309
Spray	1	698326	698326	22.400
P	1	1469494	1469494	47.137
N	1	504825	504825	16.193
Spray x P	1	32533	32533	1.044
Spray x N	1	40510	40510	1.299
P x N	1	154116	154116	4.944
Spray x P x N	1	7728	7728	0.248
Error (1)	21	654668	31175	1.303
Time	11	2198415	199856	8.353
Time x Spray	11	405100	36827	1.539
Time x P	11	407882	37080	1.550
Time x N	11	332686	30244	1.264
Time x Spray x P	11	583683	53062	2.218
Time x Spray x N	11	388076	35280	1.474
Time x P x N	11	230863	20988	0.877
Error (2)	275	6580027	23927	
Total	383	15141813		

4.27. Analysis of Variance - Effect of time of harvest, fungicidal sprays and NP fertiliser on total fresh head yield (g/m^2)

Source of Var.	DF	SS	MS	VR
Block	3	216977	72326	2.877
Spray	1	453070	453070	20.855
P	1	570070	570070	26.240
N	1	69383	69383	3.194
Spray x P	1	8883	8883	0.409
Spray x N	1	839	839	0.439
P x N	1	24284	24284	1.118
Spray x P x N	1	18006	18006	0,829
Error (1)	21	456229	21725	0.864
Time	11	55959744	5087249	202.538
Time x Spray	11	571538	51958	2.061
Time x P	11	635873	57801	2.299
Time x N	11	194118	17647	0.702
Time x Spray x P	11	480254	43659	1.736
Time x Spray x N	11	380082	34553	1.374
Time x P x N	11	208060	18915	0.752
Error (2)	275	6914147	25142	
Total	383	67161557		

4.28. Analysis of Variance - Effect of time of harvest, fungicidal sprays and NP fertiliser on fresh yield of stem and leaves (g x Exp.)*

Source of Var.	DF	SS		MS		VR
Block	3	6.685E	6	2.228E	6	0.520
Spray	1	7.486E	6	7.486E	6	19.482
P	1	1.246E	7	1.246E	7	32.418
N	1	9.256E	6	9.256E	6	24.087
Spray x P	1	4.939E	5	4.939E	5	1.285
Spray x N	1	4.808E	4	4.808E	4	0.125
P x N	1	1.444E	6	1.444E	6	3.759
Spray x P x N	1	9.096E	2	9.096E	2	0.000
Error (1)	21	8.069E	6	3.843E	5	1.124
Time	11	1.266E	9	1.151E	8	336.827
Time x Spray	11	8.934E	6	8.122E	5	2.376
Time x P	11	1.352E	7	1.229E	6	3.959
Time x N	11	1.509E	7	1.372E	6	4.014
Time x Spray x P	11	4.757E	6	4.325E	5	1.265
Time x Spray x N	11	5.915E	6	5.377E	5	1.573
Time x P x N	11	5.993E	6	5.449E	5	1.594
Error (2)	275	9.399E	7	3.416E	5	
Total	383	1.461E	9			

* In both appendices 4.28 and 4.29 the numbers preceding the letter E in the sum of squares and mean square columns are multiplied by 10 to the power indicated by the number following E to give the actual yield in g/m^2.

4.29. Analysis of Variance - Effect of time of harvest, fungicidal sprays and NP fertiliser on fresh yield of total plant (g x Exp.)*

Source of Var.	DF	SS	MS	VR
Block	3	9.161E 6	3.054E 6	5.861
Spray	1	1.162E 7	1.162E 7	20.329
P	1	1.836E 7	1.836E 7	32.123
N	1	1.092E 7	1.092E 7	19.114
Spray x P	1	6.345E 5	6.345E 5	1.110
Spray x N	1	6.140E 4	6.140E 4	0.107
P x N	1	1.842E 6	1.842E 6	3.223
Spray x P x N	1	2.716E 4	2.716E 4	0.048
Error (1)	21	1.200E 7	5.716E 5	1.097
Time	11	1.809E 9	1.644E 8	315.615
Time x Spray	11	1.379E 7	1.254E 6	2.407
Time x P	11	1.968E 7	1.789E 6	3.434
Time x N	11	1.760E 7	1.600E 6	3.070
Time x Spray x P	11	7.994E 6	7.268E 5	1.395
Time x Spray x N	11	8.843E 6	8.039E 5	1.543
Time x P x N	11	8.248E 6	7.498E 5	1.439
Error (2)	275	1.433E 6	5.210E 5	
Total	383	2.093E 9		

* See footnote for appendix 4.28.

4.30. Analysis of Variance - Effect of time of harvest, fungicidal sprays and NP fertiliser on total number of capsules per metre^2(No./m^2).

Source of Var.	DF	SS	MS	VR
Block	3	1106.8	368.9	1.315
Spray	1	2833.5	2833.5	9.811
P	1	34958.8	34958.8	121.051
N	1	9269.9	9269.9	32.099
Spray x P	1	148.9	148.9	0.516
Spray x N	1	1184.1	1184.1	4.100
P x N	1	3766.9	3766.9	13.044
Spray x P x N	1	382.2	382.2	1.323
Error (1)	21	6064.7	288.8	1.030
Time	11	9146.8	831.5	2.964
Time x Spray	11	3902.3	354.8	1.265
Time x P	11	4559.0	414.5	1.478
Time x N	11	2728.2	248.0	0.884
Time x Spray x P	11	4602.4	418.4	1.492
Time x Spray x N	11	6161.4	560.1	1.997
Time x P x N	11	2235.9	203.1	0.724
Error (2)	275	77137.7	280.5	
Total	383	170187.4		

APPENDIX 5

THE EFFECT OF FUNGI ON MORPHINE PRODUCTION

5.1. Effect of fungi on morphine concentration of ground capsules (%)

(Date on which Table 41 is based)

Treatment	Replication				
	1	2	3	4	5
Alternaria	0.18	0.11	0.19	0.13	0.16
Cladosporium	1.26	1.19	1.18	1.19	1.26
Helminthosporium	0.13	0.11	0.11	0.11	0.06
Moist Uninoculated	1.24	1.29	1.27	1.26	1.20
Dry Uninoculated	1.40	1.38	1.40	1.44	1.42

5.1. Analysis of Variance - morphine concentration of fungal infected ground capsules (%)

Source of Var.	DF	SS	MS	F. Ratio
Treatment	4	8.226	2.057	2057**
Error	20	0.020	0.001	
Total	24	8.246		

5.2. Effect of Fungi on the Morphine Concentration of Intact Capsules

5.2.1. Effect of level of fungal infection and fertiliser treatment on morphine concentration of intact capsules (%)

(Data on which Table 43 is based)

Replication	Infection category and fertiliser treatments			
	Slight			
	N0P0	N1P0	N0P1	N1P1
1	1.42	1.54	1.29	1.49
2	1.27	1.25	1.15	1.24
3	1.39	1.39	1.22	1.39
4	1.31	1.48	1.21	1.43
	Medium			
1	0.96	1.31	1.29	1.24
2	1.13	1.12	1.23	1.20
3	1.21	1.30	1.23	1.26
4	1.08	1.20	1.10	1.22
	Severe			
1	1.07	1.28	0.78	1.12
2	1.16	1.11	0.83	1.09
3	1.13	1.12	1.10	1.21
4	0.79	1.26	1.01	1.18

5.2.1. Analysis of Variance - effect of fertiliser and fungi on morphine concentration of intact capsules (%)

Source of Var.	DF	SS	MS	VR
Blocks	3	0.0662	0.0221	1.1918
Fertiliser	3	0.2028	0.0676	5.874**
Error (1)	9	0.1036	0.0115	
Infection	2	0.5734	0.2867	34.840**
Fertiliser x Infection	6	0.0982	0.0164	1.989
Error (2)	24	0.1975	0.0082	
Total	47	1.2418		

5.2.2. Effect of fertiliser on the proportion of total numbers of capsules per plot in the severely fungal infected category (%)

(Data on which Table 44 is based)

Treatment	Replication			
	1	2	3	4
N0P0	9.4	8.2	9.8	5.7
N1P0	10.7	16.2	7.4	17.2
N0P1	3.3	6.9	6.5	4.5
N1P1	23.1	25.3	18.7	19.1

5.2.2. Analysis of Variance - Effect of fertiliser on capsule number per plot in severely fungal infected category (%)

Source of Var.	DF	SS	MS	VR
Blocks	3	27.455	9.152	1.0
P	1	32.490	32.490	3.4
N	1	434.723	434.723	45.2**
N X P	1	135.723	135.723	14.1**
Error	9	86.470	9.608	
Total	15			

5.3. The Effect of Fungicidal Sprays at Different Times of Harvest on Fungal Colonisation of Intact Capsules

5.3.1. Effect of fungicidal sprays and time of harvest on percentage infection of terminal capsule segments from N1P1 treatment (%)

(Data on which Table 50 is based)

Harvest Number	Replication							
	1		2		3		4	
	Spray	Non-Spray	Spray	Non-Spray	Spray	Non-Spray	Spray	Non-Spray
2	49	49	41	44	47	43	50	42
3	43	45	38	49	61	49	32	57
4	47	52	47	34	49	38	33	46
5	37	63	50	57	72	46	44	56
6	53	48	58	50	46	54	52	55
7	67	48	45	59	76	56	54	57
8	75	Mix	84	76	55	88	81	73
12	92	64	89	86	90	90	93	93

5.3.1. Analysis of Variance - effect of fungicidal spray and time of harvest on percentage infection of terminals capsule segments from N1P1 treatment (%)

Source of Var.	DF	SS	MS	VR
Block	3	116.36	38.79	0.464
Spray	1	0.67	0.67	0.011
Error (1)	3	183.18	61.06	0.730
Harvest Time	7	13844.94	1977.85	23.649**
Spray x Time	7	367.15	52.45	0.627
Error (2)	41 (1)	3428.91	83.63	
Total	62	17941.22		

5.3.2. Effect of fungicidal sprays and fertiliser on percentage infection of terminal capsule segments from harvests 8 and 12. (Data on which Table 51 is based)

Harvest No.	Replicate	Sprayed				Non-Sprayed			
		N0 P0	N1 P0	N0 P1	N1 P1	N0 P0	N1 P0	N0 P1	N1 P1
8	1	63	59	83	75	46	64	63	Miss
	2	74	74	82	84	73	67	72	76
	3	81	65	55	55	62	73	80	88
	4	58	72	71	81	94	87	Miss	73
12	1	90	83	Miss	92	85	94	90	64
	2	87	93	94	89	97	90	85	86
	3	77	85	76	90	90	94	98	90
	4	80	88	96	93	89	95	76	93

5.3.2. Analysis of Variance - effect of fungicidal sprays and fertiliser on percentage infection of terminal capsule segments from harvests 8 and 12 (%).

Source of Var.	DF	SS	MS	VR
Block	3	498.85	166.28	2.666
Spray	1	0.17	0.17	0.001
P	1	17.48	17.48	0.105
N	1	24.00	24.00	0.144
Spray X P	1	329.67	329.67	1.978
Spray X N	1	7.49	7.49	0.045
P X N	1	18.93	18.93	0.114
Spray X P X N	1	4.05	4.05	0.024
Error (1)	21	3500.28	166.68	2.672
Harvest Time	1	5098.94	5098.94	81.745
Time X Spray	1	0.32	0.32	0.005
Time X P	1	23.46	23.46	0.376
Time X N	1	10.48	10.48	0.168
Time X Spray X P	1	51.57	51.57	0.827
Time X Spray X N	1	40.95	40.95	0.656
Time X P X N	1	56.06	56.06	0.899
Error (2)	22	1372.28	62.38	
Total	60	11054.98		

5.3.3. Effect of fungicidal sprays and N P fertiliser on the focus of fungal colonisation on the surfaces of terminal capsules at harvest 12 (True geographic bearing in degrees)

(Data on which Table 53 is based)

Treatment	Replication							
	1		2		3		4	
	Spray	Non-spray	Spray	Non-spray	Spray	Non-spray	Spray	Non-spray
NOPO	44	16	10	27	48	35	35	33
N1P1	34	32	27	34	18	24	46	23
NOP1	28	20	20	24	32	15	20	32
N1P1	16	19	27	43	44	29	15	10

Each value 3.3 is the mean of 20 capsules per plot

5.3.3. Analysis of Variance - effect of fungicidal sprays and N P fertiliser on fungal colonisation on the surfaces of terminal capsules at harvest 12 (True geographic bearing in degrees)

Source of Var.	DF	SS	MS	VR
Block	3	105.8	35.3	0.255
P	1	264.5	264.5	1.912
N	1	0.1	0.1	0.001
Spray	1	72.0	72.0	0.520
P x N	1	15.1	15.1	0.109
P x Spray	1	24.5	24.5	0.177
N x Spray	1	15.1	15.1	0.109
P x N x Spray	1	1.1	1.1	0.008
Error	21	2905.8	138.4	
Total	31	3404.0		

5.3.4. Effect of fungicidal sprays and N P fertiliser on the angular range of fungal colonisation on the surfaces of terminal capsules at harvest 12 (True geographic bearing in degrees).

(Data on which Table 53 is based)

Treatment	Replication							
	1		2		3		4	
	Spray	Non-spray	Spray	Non-spray	Spray	Non-spray	Spray	Non spray
N0P0	125	136	105	113	116	123	137	159
N1P0	121	121	98	130	96	113	119	141
N0P1	103	113	113	126	98	117	89	161
N1P1	113	129	83	135	108	125	109	116

Each value in 3.4 is the mean of 20 capsules per plot.

5.3.4. Analysis of Variance - Effect of fungicidal sprays and N P fertiliser on the angular range of fungal colonisation on the surfaces of terminal capsules at harvest 12 (Degrees).

(Data on which Table is based)

Source of Var.	DF	SS	MS	VR
Block	3	1473.3	491.1	2.775
P	1	413.3	413.3	2.335
N	1	185.3	185.3	1.047
Spray	1	3300.8	3300.8	18.649
P x N	1	166.5	166.5	0.941
P x Spray	1	236.5	236.5	1.336
N x Spray	1	0.0	0.0	0.000
P x N x Spray	1	63.3	63.3	0.358
Error	21	3716.9	177.0	
Total	31	9556.0		

5.3.5. Effect of fungicidal sprays and N P fertiliser on the superficial fungal cover of terminal capsules (Arcsin percent)
(Data on which Table 54 is based)

Hvst. No.	Treatment	Replication							
		1		2		3		4	
		Spray	Non-Spray	Spray	Non-Spray	Spray	Non-Spray	Spray	Non-Spray
10	N0 P0	0.00	9.10	0.00	5.74	0.00	17.95	0.00	17.46
	N1 P0	4.05	10.78	4.05	17.95	4.05	17.46	0.00	17.95
	N0 P1	4.05	20.27	0.00	16.95	5.74	12.25	7.03	18.91
	N1 P1	9.10	13.56	12.11	20.27	9.10	18.91	7.03	16.43
11	N0 P0	4.05	17.46	5.74	12.25	5.74	16.43	7.03	17.95
	N1 P0	9.10	15.34	5.74	14.18	7.03	11.54	5.74	18.43
	N0 P1	8.13	16.43	7.03	16.95	5.74	15.34	4.05	18.91
	N1 P1	5.74	24.35	5.74	19.82	5.74	15.89	5.74	17.95
12	N0 P0	5.74	16.43	5.74	15.34	0.00	17.95	4.05	20.27
	N1 P0	4.05	11.54	4.05	10.78	0.00	13.56	0.00	15.34
	N0 P1	11.54	21.97	11.54	14.77	9.10	13.56	9.10	16.95
	N1 P1	7.03	19.37	5.74	19.37	4.05	14.18	4.05	16.95

5.3.5. Analysis of Variance - effect of fungicidal sprays and N P fertiliser on the superficial fungal cover of terminal capsules (Arcsin percent)

Source of Var.	DF	SS	MS	VR
Block	3	21.888	7.296	1.193
Spray	1	2916.995	2916.995	254.630
P	1	202.827	202.827	17.705
N	1	1.586	1.586	0.138
Spray X P	1	3.110	3.110	0.272
Spray X N	1	0.144	0.144	0.013
P X N	1	1.441	1.441	0.126
Spray X P X N	1	12.601	12.601	1.100
Error (1)	21	240.572	11.456	1.873
Harvest	2	37.411	18.706	3.059
Harvest X Spray	2	3.910	1.955	0.320
Harvest X P	2	35.300	17.650	2.886
Harvest X N	2	131.806	65.903	10.776
Harvest X Spray X P	2	42.618	21.309	3.484
Harvest X Spray X N	2	14.629	7.315	1.196
Harvest X P X N	2	3.398	1.699	0.278
Error (2)	50	305.790	6.116	
Total	95	3976.026		

5.3.6. Effect of fungicial sprays and N P fertiliser on the superficial fungal cover of lateral capsules (Arcsin percent)
(Data on which Table 54 is based)

Hvst. No.	Treatment	Replication							
		1		2		3		4	
		Spray	Non-Spray	Spray	Non-Spray	Spray	Non-Spray	Spray	Non-Spray
10	N0 P0	5.13	5.74	0.00	6.55	0.00	11.24	0.00	7.49
	N1 P0	9.97	4.44	4.44	7.49	6.55	9.10	0.00	0.00
	N0 P1	4.44	20.09	0.00	16.43	6.55	8.13	7.49	19.75
	N1 P1	7.92	6.80	5.74	15.89	8.53	10.14	7.71	0.00
11	N0 P0	0.00	16.64	0.00	12.92	8.13	10.47	9.10	13.56
	N1 P0	6.02	15.34	4.44	12.92	0.00	9.97	4.80	19.37
	N0 P1	13.69	11.83	9.10	13.56	4.44	11.24	0.00	16.51
	N1 P1	3.14	17.66	4.80	14.18	6.80	7.92	6.02	9.80
12	N0 P0	0.00	12.92	6.55	9.10	0.00	17.26	0.00	12.92
	N1 P0	0.00	8.13	4.80	6.55	0.00	6.80	0.00	12.11
	N0 P1	4.80	22.79	5.74	20.70	10.94	12.92	0.00	12.92
	N1 P1	0.00	11.83	0.00	15.00	0.00	9.80	3.63	17.68

5.3.6. Analysis of Variance - effect of fungicidal sprays on the superficial fungal cover of lateral capsules (Arcsin percent)

Source of Var.	DF	SS	MS	Fn
Block	3	27.75	9.25	0.599
Spray	1	1512.01	1512.01	122.504
P	1	166.08	166.08	13.456
N	1	59.20	59.20	4.797
Spray X P	1	5.41	5.41	0.438
Spray X N	1	57.33	57.33	4.645
P X N	1	26.49	26.49	2.146
Spray X P X N	1	0.01	0.01	0.001
Residual	21	259.19	12.34	0.798
Harvest	2	81.30	40.65	2.628
Harvest X Spray	2	153.08	76.65	4.948
Harvest X P	2	61.61	30.81	1.991
Harvest X N	2	37.64	18.82	1.217
Harvest X Spray X P	2	46.71	23.35	1.510
Harvest X Spray X N	2	99.97	49.99	3.231
Harvest X P X N	2	3.77	1.89	0.122
Residual	50	773.48	15.47	
Total	95	3371.06		