CONTRACT REPORT

Drilled Horticultural Crops: Preliminary Evaluation of Fresh Primed Seed

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PRACTICAL SECTION FOR GROWERS

Objectives and background

Recent developments in seed priming technology have resulted in primed vegetable seeds becoming available to growers. Primed seeds germinate more rapidly and more uniformly than natural seeds. This can lead to an earlier and more uniform crop than that obtained from natural seeds. The priming process involves hydrating seeds to a moisture content just below that which enables germination, and keeping them at this moisture content for typically seven to fourteen days. The seeds are then normally dried to facilitate storage. Experiments have shown that primed seeds which have not been dried (fresh primed seeds), germinate even more rapidly and uniformly than dried primed seeds. The first objective of the work described in this report was to investigate the effects of storage on the viability and vigour of fresh primed salad onion seeds, to determine whether the storage life is sufficient to allow their use by growers. A second objective was to compare the establishment and early growth in field experiments of natural, conventionally (dried) primed and fresh primed seeds sown with or without water pumped into the seed furrow during drilling, to determine whether the benefits are sufficient to justify the use of fresh primed seed in commercial production.

Summary of results

Fresh primed seeds (seeds which have been primed but not dried) are not normally available to growers but they could be made available if there is sufficient benefit from their use. A potential difficulty is their supposed limited shelf life. Experiments were carried out to determine the effect of storage at 5°C and 15°C on the germination (production of a visible radicle) of fresh primed seed. There were no effects at either temperature of storage times up to 30 days on the percentage germination. At both temperatures the germination time and the standard deviation of germination times were reduced by storage times up to 20 days, indicating that the speed and uniformity of germination both improved with storage. Seedlings grown from fresh primed seed were evaluated by measuring their root length, weight, and the percentage of normal seedlings according to the International Seed Testing Association test. There was no deterioration in any of these properties at either temperature for storage times up to 20 days.

Four field experiments were carried out in 1995 at HRI Wellesbourne, in which natural, dried primed and fresh primed seeds were drilled with 0, 8.2 or 18.6 ml of water injected into each metre of the seed furrow. The injection of water was beneficial in the March sowing, had little effect in the May and July sowing, but had a detrimental effect in the September sowing. The emergence of seedlings from fresh primed seed was always faster than that from either dried primed or natural seed. The seedlings produced from fresh primed seeds were always heavier than those from natural seed. The best results were from the March sowing when, compared with natural seed drilled without water, fresh primed seed drilled with 8.2 ml of water per metre of row, reduced emergence time from 27.6 to 18.2 days, increased mean seedling weight from 0.35 to 0.69 g and reduced the coefficient of variation of seedling weight from 70.6 to 46.8 %.

Two field experiments were carried out in 1996 on a commercial farm in Kent again using natural, dried primed and fresh primed seed. Water was not added from the seed drill. For the first sowing (24/4) plots were either covered with polythene or left uncovered. Fresh primed seed emerged about one day earlier than dried primed seed but otherwise behaved like dried primed seed. Uncovered natural seed took about 32 days to emerge. Covering reduced this time by about 7 days and priming (fresh) reduced it by a further 5 days so that covered fresh primed seed emerged in about 20 days. These differences were reflected in the measured fresh weight of crop (g/m row) at maturity. Covering natural seed increased fresh weight by 33%, priming (fresh or dry) increased it by 25% and both increased it by 59%. In the second experiment (which was not covered) both priming treatments had a similar effect on fresh weight, increasing it by 45%.

EXPERIMENTAL SECTION

Introduction

Compared with natural seeds, primed seeds generally emerge more quickly and over a shorter time interval. In many instances this produces an earlier (or larger) and a more uniform crop. Early priming methods were developed by Hydecker et al (1973) who primed seeds by placing them in contact with an osmotic solution, usually the high molecular weight polymer polyethylene glycol (PEG). The effect of the osmoticum was to limit the quantity of water absorbed by the seeds to an amount which would enable them to carry out much of the pregerminative metabolism, but not to actually germinate. The seeds remained in contact with the osmoticum for periods typically up to fourteen days, and were then removed from the solution, washed and dried back to the normal storage water content.

Over the past ten years HRI Wellesbourne has been one of the major centres in the world doing research into seed priming. In the mid 1980's, working with the Chemical Engineering Department of Birmingham University, systems were developed which could prime up to 20 kg of seed in large vessels containing aerated solutions of PEG. (Buljalski et al 1989, Buljalski & Nienow 1991). These systems were used by industry but problems associated with the disposal of large quantities of PEG solution prevented the technique being used on a large scale. These problems were solved by the invention of Drum Priming at HRI Wellesbourne (Rowse 1991, Rowse 1996). Seeds to be drum primed are first tested to determine the appropriate degree of hydration and then placed in a horizontal drum which is rotated about its horizontal axis while water is slowly added. Depending on species, the addition of water generally takes one or two days. It is controlled by a computer so that, at any instant, the rate of addition is always less than the natural imbibition rate of the seeds. This ensures that the seeds never appear wet and are always free flowing. Following hydration the seeds are incubated in a slowly rotating drum for a period of up to fourteen days during which time the developmental processes occur within the seed. After incubation the primed seeds are normally dried to facilitate storage. "Fresh" primed seeds are seeds which have not been dried after priming. They are surface dry and if treated properly can be drilled with most kinds of drill mechanism. Fresh primed seeds can germinate extremely rapidly but it has generally been assumed that their supposedly limited shelf life would prevent their use in commerce. However it is probable that ways of storing fresh primed seeds could be devised if the benefits to crop were sufficient. The Drum Priming system has been patented by the British Technology Group and is being used under license in several countries. Elsoms Seeds Ltd of Spalding are the sole British licensee. The two main objectives of this project were:

1 To determine the effects of storage of fresh primed salad onion seed at 5°C and 15°C on the germination and seedling growth under laboratory conditions.

2 To compare the effects on seedling emergence and seedling weight of sowing natural, dried primed and fresh primed salad onion seed, with either zero, 8.2 or 18.6 ml of water applied per meter of row in the seed furrow.

Priming treatments

Drum priming is particularly suitable for priming large quantities of seed (e.g. 20 kg batches) and would be the method used if fresh primed seed were to be produced commercially. However the quantities of seed required for this trial were too small to prime accurately with the drum priming equipment available, so a similar technique was used which has been designed for priming small quantities of flower seed (Rowse 1994). The method gives very similar results to drum priming but can more readily be used with small quantities of seed. In this method the rotating drum into which the seeds are placed is made of a semipermeable material which is surrounded by a second larger drum containing a solution of PEG. The seeds absorb water through the walls of the inner drum and eventually achieve an equilibrium water content which is determined by the strength of the PEG solution. The seeds for all the experiments were primed for 12 days at 15°C at a nominal potential of -1.6 MPa.

EXPERIMENTS ON THE STORAGE LIFE OF FRESH PRIMED SEED

Materials and methods

The flower seed priming technique described above was used to prime 100 g of salad onion seeds (Tozer Winter White Bunching treated with thiram and benlate). After priming the seeds were divided into two equal amounts and each portion placed in a flower seed priming drum with a potential of -2.0MPa and stored at either 5°C or 15°C. Samples were removed from each container after 0, 5, 10, 15, 20, 25 and 30 days after the end of the priming treatment. On each occasion four replicates of 100 seeds were placed on moist filter paper in boxes measuring 120 by 80mm. The boxes were maintained at 15°C and examined daily when all germinated seeds were counted and removed. Counting was halted after the flush of germination when three days had elapsed without any recorded germination. If N was the number of seeds in the sample, f_i the number germinating in each time interval between counts, and x_i the elapsed time from the start of the test to the midpoint of the time interval, then the percentage germination, mean germination time (a measure of speed), and the standard deviation of the germination times (a measure of uniformity of germination) were calculated according to the following;

$$\% \quad \text{Germination} = \frac{100\sum f_i}{N}$$

$$\text{Mean germination time} = \frac{\sum f_i x_i}{\sum f_i}$$

$$\text{S. D. of germination time} = \sqrt{\frac{\sum (f_i x_i^2) - {(\sum f_i x_i)^2}/{\sum f_i}}{\sum f_i - 1}}$$

A seedling evaluation test was also carried out in which seedlings were grown from seeds stored for 0, 5, 10, 15, 20, 25, and 30 days at both temperatures. On each occasion, six replicates each of 20 seeds were placed on near vertical sheets of moist paper. The lower edge of the papers dipped into a reservoir of water so that the paper was moist throughout the test, and a transparent cover was placed over the equipment to minimise evaporation. Details of the method are given by Gray and Steckel (1983). The seeds were grown at 20°C for 9 days when an assessment of the number of normal seedlings was made according to the method given by Anon (1979). The weights of each seedling and the length of the root were also recorded.

Results of the storage tests

The effects of storage time at the two temperatures on the percentage germination of fresh primed salad onion seed are shown in Table 1. Although there were small differences, there was no consistent effect of storage time on the recorded germination percentage. The percentage germination after 30 days storage at either temperature was similar to that recorded after zero days storage. There was an interesting effect of storage time on the mean germination time (Table 2). It was quite clear that the speed of germination increased (mean germination time decreased) at both temperatures for storage periods of up to 20 days. There was little further change in the rate of germination for storage periods between 20 and 30 days. This effect was almost certainly caused by additional priming occurring during storage. Fresh primed seeds stored for 20 days germinated almost twice as quickly as those that had not been stored. The effects of storage on the standard deviation of storage times (a measure of uniformity of germination) are shown in Table 3. There was a small trend for the standard deviation to decrease with time which is probably of little consequence. Most importantly there was no significant reduction in uniformity of germination caused by storing the seeds for up to 30 days at either temperature.

The effect of storage time on the percentage of normal seedlings is shown in Table 4. There appeared to be a trend for the number of normal seedlings to decrease with storage time. To identify the storage time at which a statistically significant decrease occurred, the value for each storage time was compared to the mean of the values for all shorter times. On this basis there was a significant fall in the number of normal seedlings after 25 days storage at 15°C. There were no significant reductions for fresh seed stored at 5°C. The same analysis was used on the length of the seedling roots (Table 5). The roots of seedlings produced from fresh primed seed after 25 days storage were significantly shorter than the mean of the values for shorter storage periods at either temperature. There were no significant reductions in the fresh weight of seedlings produced from fresh primed seed stored for any length of time at either temperature (Table 6).

Storage time (days)	0	5	10	15	20	25	30
	Percentage germination						
Storage Temp 5°C	97.0	98.3	95.5	99.3	97.5	99.3	99.3
Storage temp 15°C	97.3	97.0	95.3	95.3	98.0	96.0	96.5

Table 1 Effect of storage at 5°C and 15°C on the percentage germination of fresh primed salad onion seed.

Storage time (days)	0	5	10	15	20	25	30
	Mean germination time (days)						
Storage Temp 5°C	1.48	1.05	0.98	0.88	0.75	0.75	0.75
Storage temp 15°C	1.33	1.03	0.93	0.93	0.63	0.73	0.60

Table 2 Effect of storage at 5°C and 15°C on the mean germination time of fresh primed salad onion seed.

Storage time (days)	0	5	10	15	20	25	30
	Standard deviation of germination times (days)						
Storage Temp 5°C	0.78	0.73	0.68	0.70	0.58	0.53	0.75
Storage temp 15°C	0.95	0.80	0.73	0.95	0.50	0.50	0.70

Table 3 Effect of storage at 5°C and 15°C on the standard deviation of germination times of fresh primed salad onion seed.

Storage time (days)	0	5	10	15	20	25	30
	Percentage of normal seedlings						
Storage Temp 5°C	59.9	68.9	60.5	57.0	61.8	58.8	51.0
Storage temp 15°C	60.4	70.1	59.9	56.8	52.2	48.9*	50.5

Table 4 Effect of storage time of fresh primed salad onion seeds at 5°C and 15°C on the percentage of normal seedlings. Figures marked with an * are significantly different at the 5% level from the mean of the preceding values.

Storage time (days)	0	5	10	15	20	25	30
	Mean root length (mm)						
Storage Temp 5°C	46.1	39.5	46.7	40.2	43.8	36.8*	36.5
Storage temp 15°C	44.5	40.8	44.9	40.0	43.5	37.4*	34.0

Table 5 Effect of storage time of fresh primed salad onion seeds at 5°C and 15°C on the length of the seedlings roots 9 days after sowing. Figures marked with an * are significantly different at the 5% level from the mean of the preceding values.

Storage time (days)	0	5	10	15	20	25	30
	Mean seedling weight (mg)						
Storage Temp 5°C	30.7	28.7	35.0	32.9	34.8	31.3	31.4
Storage temp 15°C	28.4	30.0	36.6	33.0	35.0	31.6	30.0

Table 6 Effect of storage time of fresh primed salad onion seeds at 5°C and 15°C on the mean seedling weight 9 days after sowing. Figures marked with an * are significantly different at the 5% level from the mean of the preceding values.

FIELD EXPERIMENTS WITH FRESH PRIMED SEED

Drilling Equipment

Drill-mounted equipment has been developed at HRI Wellesbourne to inject starter fertiliser beneath the seed during drilling. (Rowse et al 1988, Rowse 1993, Stone & Rowse 1992 & 1995). Very similar equipment is available commercially from Stanhay Webb Ltd. The liquid reservoir and landwheel-driven pumps from this equipment were used in the current experiment to supply water to specially modified seed coulters. (Fig 1, Appendix 1). Water supplied to the modified coulters was injected towards the falling seeds and into the seed furrow through a backwards facing orifice in the seed coulter. To minimise the degree of bouncing and splashing of the water falling into the seed furrow, the diameter of the orifice was matched to the flow rate of the water such that the mean velocity of the water issuing from the orifice was equal to the forward speed of the drill (i.e. the average relative motion between the water and the soil was zero).

Natural and dried primed seed were sown using a plain Stanhay belt with 96 size 10 holes and "A" bases with "T" chokes. The fresh seed was slightly larger and required a 96-hole belt with size 11 holes. The seeding rate was measured by lowering the drill land-wheels so that the coulters were clear of the ground, and running the drill at the appropriate speed (1.6 mph) cover a concrete surface covered with a length of paper towel. The towel reduced the amount of seed bounce and made the seeds easier to see. The seed rates were

Natural	58 seeds/m
Dried primed	65 seeds/m
Fresh primed	54 seeds/m

The percentage germination in the field experiments were calculated from these figures. However experience has shown that there is some random variation and rates do vary slightly, a fact which must be taken into account when comparing the percentage germination of different treatments.

Cultural and experimental details

The experiments were carried out during the spring, summer and autumn of 1995 in Little Cherry field at HRI Wellesbourne on a sandy clay loam of the Wick series. (Whitfield 1974). The soil was ploughed in the autumn of 1994, one tonne/ha of a 0:24:24 fertiliser applied and 1.52 m (5 ft wheel centre to wheel centre) beds marked out. All seedbeds were prepared approximately two weeks before sowing. A dressing of 80 kg/ha of nitrogen was applied before sowing and a further 45 kg/ha applied when the crop had fully established. Weeds were controlled by a Ramrod (9.0 l/ha) Dacthal (6.0 kg/ha) mixture applied in 500 l/ha of water and by hand weeding when necessary.

Nine treatments were considered, comprising all combinations of 3 seed types (natural, dried primed, and fresh primed) and 3 rates of water (0. 8.2 and 18.6 ml/m row). Each of the four replicate blocks of these nine treatments were further subdivided into 3 sub-blocks of 3 plots, the treatments being arranged such that each sub-block contained each seed type once and each water rate once, with different elements of the interaction term confounded with block differences in the different replicates, thus allowing the interaction term to be fully evaluated.

Counts of the number of seedlings visible in a 3 m portion of row were made at one or two day intervals until there was no increase in the number of seedlings. This data was used to calculate the percentage germination, the mean emergence time, and the standard deviation of mean emergence times (a measure of uniformity of emergence). In addition a seedling harvest was made some time after the end of emergence when all plants in a 2 m portion of row were removed and weighed individually. These data were used to calculate the mean seedling weight and the coefficient of variation of each treatment. The sowing dates, dates on which emergence counts started and ceased and the dates of the seedling harvests are shown in table 7.

	Date sown	Emergence started	Emergence ended	Seedling harvest
Sowing 1	22/3	5/4	1/5	23/5
Sowing 2	19/5	26/5	9/6	3/7
Sowing 3	17/7	23/7	11/8	21/8
Sowing 4	14/9	22/9	13/10	20/10

Table 7 Dates during 1995 when crops were sown, emergence counts started and ended, and seedling harvests were taken.

Sowing of 22/3/95

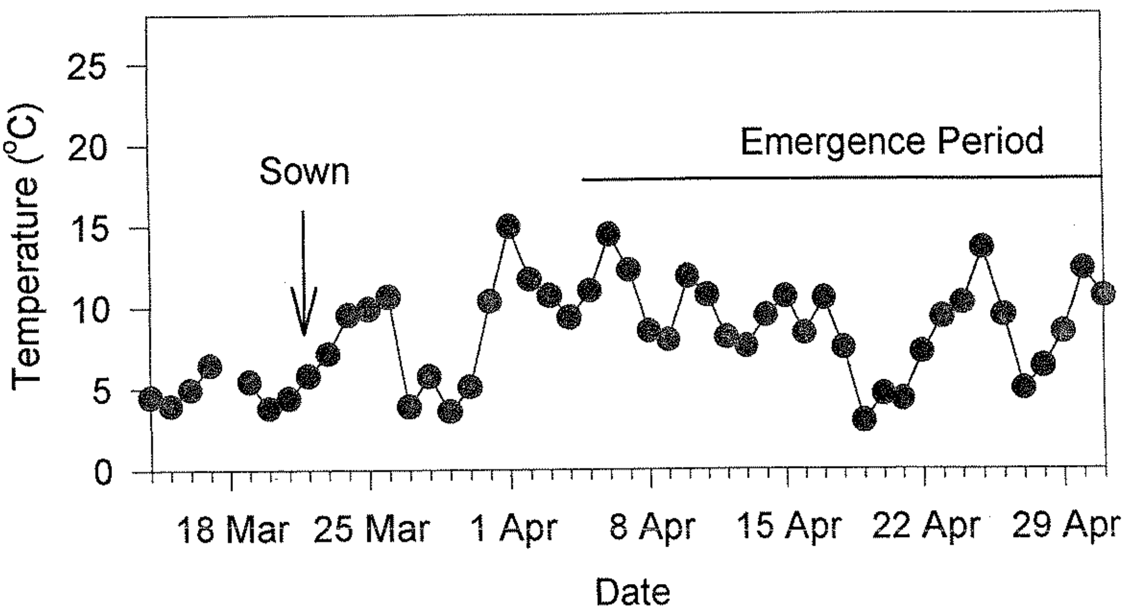
The rainfall and mean air temperature during the germination and establishment periods are shown in Fig 2). The percentage emergence, mean emergence time and SD of emergence times are shown in tables 8, 9 and 10, respectively and the mean seedling weights and CV of seedling weights are shown in Tables 11 and 12, respectively. Unless otherwise stated all differences noted below were significant at the 5% level.

Considering the mean of all seed treatments, the addition of water at 8.2 or 18.6 ml/m row increased the percentage germination from 46.8 for natural seed, to 52.0 and 53.9%, respectively (Table 8). It also reduced the emergence time from 23.6 to 21.2 and 20.5 days, (Table 9) and reduced the SD of emergence times from 5.98 to 4.84 and 4.35 days (Table 10). The differences between the two rates of water were not significant. These differences were reflected in the seedling harvest, where the addition of water at 8.2 and 18.6 ml/m row increased the mean seedling weight from 0.42 g to 0.54 and 0.52 g respectively (Table 11), and reduced the CV of seedling weight from 72.0 to 57.4 and 53.3 %. (Table 12). Again the differences between the two rates of water were not significant.

Neither priming treatment had any effect on percentage emergence or the SD of emergence times (Tables 8 & 9). However the dried primed treatment reduced the emergence time from 25 days for natural seed to 21.2 days. The fresh primed seed emerged in 19.1 days which was significantly faster than the dried primed seed. These differences were reflected in the seedling weights (Table 11). Seedlings produced from natural seed had a mean weight of 0.40g, those from dried primed seed were 0.50g and those from fresh primed seed were 0.58g.

Compared with natural seed drilled without water the combined effect of sowing fresh primed seed with 8.2 ml of water per metre of row was to reduce emergence time from 27.6 to 18.2 days, to increase seedling weight from 0.35 to 0.69g and to reduce the CV of seedling weight from 70.6 to 46.8%.

Sowing of the 22/3/95



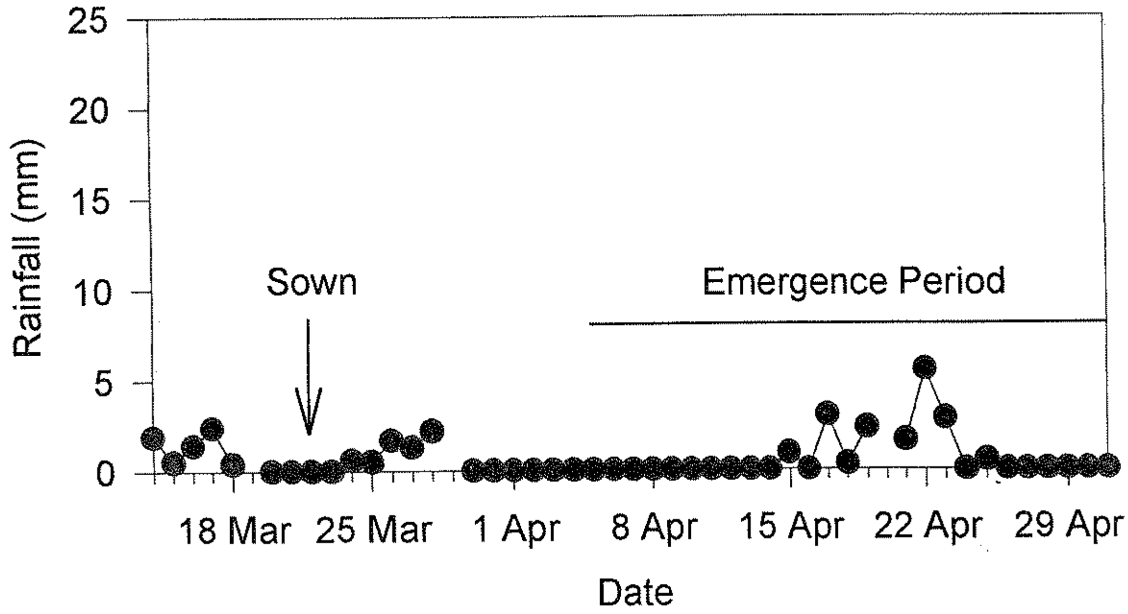


Fig 2

Mean air temperature and rainfall during germination and establishment of crop sown on 22/3/95

Percentage Emergence				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	51.5	52.7	56.6	53.6
Dried Primed	44.3	48.3	56.6	49.7
Fresh Primed	44.5	54.9	48.5	49.3
Mean	46.8	52.0	53.9	

Table 8 Sowing of 22/3/95 - Percent emergence. LSD (5%, 16 df):- means of seed treatment or water rate 4.32; within a seed treatment or water rate 9.65; with dissimilar water and seed treatments 8.63.

Mean Emergence Time (days)				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	27.6	24.4	22.9	25.0
Dried Primed	22.5	21.0	20.1	21.2
Fresh Primed	20.7	18.2	18.6	19.1
Mean	23.6	21.2	20.5	

Table 9 Sowing of 22/3/95 - Mean emergence time. LSD (5%,16 df):-means of seed treatment or water rate 0.80; within a seed treatment or water rate 1.80; with dissimilar water and seed treatments 1.61.

Standard Deviation of Emergence Times (days)				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	5.65	5.29	3.88	4.94
Dried Primed	5.99	5.04	4.40	5.14
Fresh Primed	6.31	4.19	4.77	5.09
Mean	5.98	4.84	4.35	

Table 10 Sowing of 22/3/95 - SD of emergence times. LSD (5%,16 df):-means of seed treatment or water rate 0.82; within a seed treatment or water rate 1.84; with dissimilar water and seed treatments 1.64.

Mean Seedling Weight (g)				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	0.35	0.43	0.42	0.40
Dried Primed	0.41	0.49	0.60	0.50
Fresh Primed	0.50	0.69	0.53	0.58
Mean	0.42	0.54	0.52	

Table 11 Sowing of 22/3/95 - Mean seedling weight. LSD (5%,16 df) for comparing means of seed treatment or water rate 0.06, within a seed treatment or water rate 0.14, with dissimilar water and seed treatments 0.13.

Coefficient of Variation (%)				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	70.6	59.8	51.1	60.5
Dried Primed	69.3	65.6	47.5	60.8
Fresh Primed	76.1	46.8	61.3	61.4
Mean	72.0	57.4	53.3	

Table 12 Sowing of 22/3/95 - Coefficient of variation of seedling weight. LSD (5%,16 df) for comparing means of seed treatment or water rate 8.3, within a seed treatment or water rate 18.7, with dissimilar water and seed treatments 16.7

Sowing of 19/5/95

The rainfall (with irrigation) and mean air temperature during germination and establishment are shown in Fig 3. The percentage emergence, mean emergence time and SD of emergence times are shown in Tables 13, 14 and 15, respectively and the mean seedling weight and CV of seedling weights are shown in Tables 16 and 17, respectively. Unless otherwise stated all differences noted below were significant at the 5% level.

In contrast to the first sowing, the addition of water at either rate had no significant effect on any of the emergence parameters or indeed on the seedling weight or coefficient of variation.

The percentage emergence of dried primed seed (67.0%) and fresh primed seed (64.7%) were both greater than that of the natural seed (57.6 %) (Table 13). Compared with the emergence time of natural seed (12.3 days), dried primed seed emerged more quickly (10.4 days) but the fresh primed seed (8.9 days) was faster than either (Table 14). There were no effects of seed treatment on the SD of emergence times. The faster emergence of the seed from both priming treatments was again reflected in the seedling weights (Table 16). Seedlings produced from natural seed had a mean weight of 1.04g, those from dried primed seed were 1.21g and those from fresh primed seed were 1.39g. There was no effect of seed treatment on the CV of seedling weight (Table 17).

Sowing of the 19/5/95

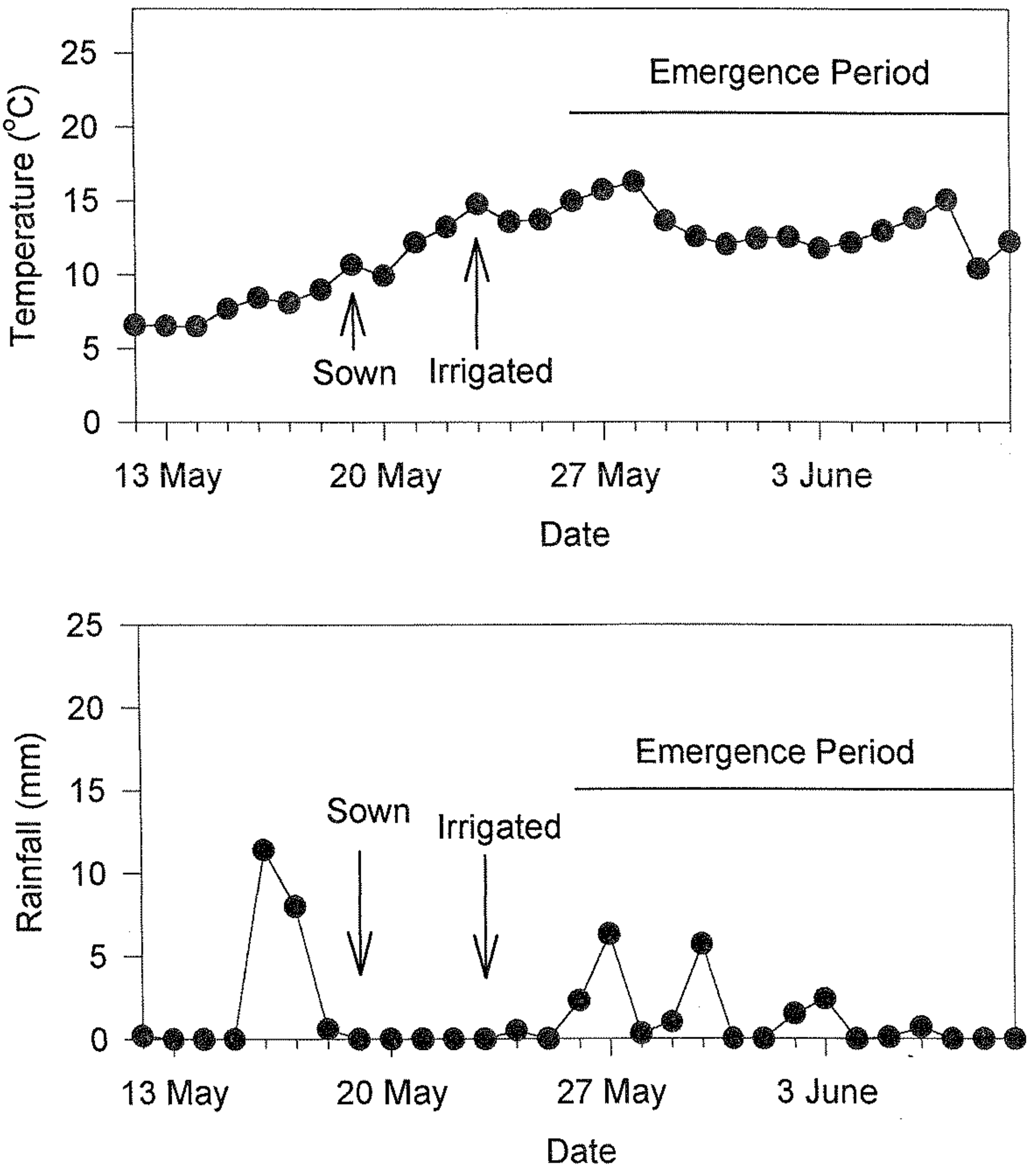


Fig 3

Mean air temperature and rainfall during germination and establishment of crop sown on 19/5/95

Percentage Emergence				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	56.3	56.6	60.4	57.6
Dried Primed	69.5	66.9	64.6	67.0
Fresh Primed	67.3	63.0	63.8	64.7
Mean	64.4	62.2	62.9	

Table 13 Sowing of 19/5/95 - Percentage emergence. LSD (5%,16 df); means of seed treatment or water rate 2.85; within a seed treatment or water rate 6.37; treatments with dissimilar water rates and seed treatments 5.70.

Mean Emergence Time (days)				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	12.2	12.3	12.3	12.3
Dried Primed	10.3	10.4	10.6	10.4
Fresh Primed	8.9	9.1	8.7	8.9
Mean	10.5	10.6	10.5	

Table 14 Sowing of 19/5/95 - Mean emergence time. LSD (5%,16 df); means of seed treatment or water rate 0.25; within a seed treatment or water rate 0.56; treatments with dissimilar water rates and seed treatments 0.50.

Standard Deviation of Germination Times (days)				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	1.40	1.59	1.58	1.52
Dried Primed	1.53	1.64	1.69	1.62
Fresh Primed	1.76	1.95	1.64	1.78
Mean	1.57	1.73	1.63	

Table 15 Sowing of 19/5/95 - SD of emergence times. LSD (5%,16 df); means of seed treatment or water rate 0.20; within a seed treatment or water rate 0.45; treatments with dissimilar water rates and seed treatments 0.40.

Mean Seedling Weight (g)				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	1.05	1.02	1.06	1.04
Dried Primed	1.19	1.26	1.18	1.21
Fresh Primed	1.49	1.34	1.33	1.39
Mean	1.25	1.21	1.19	

Table 16 Sowing of 19/5/95 - Mean seedling weight. LSD (5%,16 df) for comparing means of seed treatment or water rate 0.11, within a seed treatment or water rate, 0.24, treatments with dissimilar water rates and seed treatments 0.22.

Coefficient of Variation (%)				
	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	44.1	46.2	49.3	46.5
Dried Primed	57.6	53.5	44.4	51.8
Fresh Primed	55.9	49.6	50.0	51.8
Mean	52.5	49.7	47.9	

Table 17 Sowing of 19/5/95 - Coefficient of variation of seedling weight. LSD (5%,16 df) for comparing, means of seed treatment or water rate 10.1, within a seed treatment or water rate 22.5, treatments with dissimilar water rates and seed treatments 20.1.

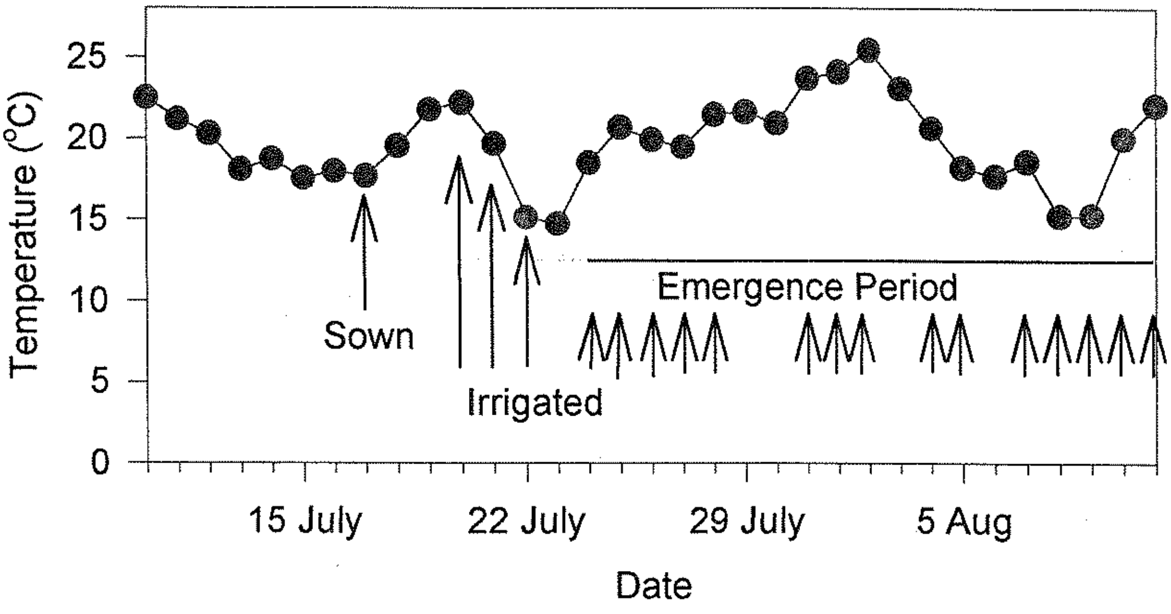
Sowing of 17/7/95

The rainfall (with irrigation) and mean air temperature during germination and establishment are shown in Fig 4. The hot dry conditions after sowing necessitated frequent irrigation. The percentage emergence, mean emergence time and SD of emergence times are shown in Tables 18, 19 and 20, respectively and the mean seedling weight and CV of seedling weights are shown in Tables 21 and 22, respectively. Unless otherwise stated all differences noted below were significant at the 5% level.

With the exception that the mean weight of seedlings grown with the addition of 8.2 ml/m of water was greater than that of seedlings grown with the addition of 18.6 ml/m row, water had no effect on any of the measured parameters.

The germination percentage of fresh primed seed (50.9%) was higher than that of the natural seed (46.0%) which in turn was higher than that of the dried primed seed (40.5) (Table 18). The fresh primed seed (7.2 days) emerged more quickly than the dried primed seed (8.7 days) which in turn emerged more quickly than the natural seed (10.1 days) (Table 19). Seed treatments had no effect on either the SD of emergence times (Table 20) or the CV of seedling weight (Table 22). However, as in the previous experiments, seedlings produced from fresh primed seeds were heavier (0.67 g) than either those produced from dried primed seed (0.51 g) or from natural seed (0.50 g) (Table 21).

Sowing of the 17/7/95



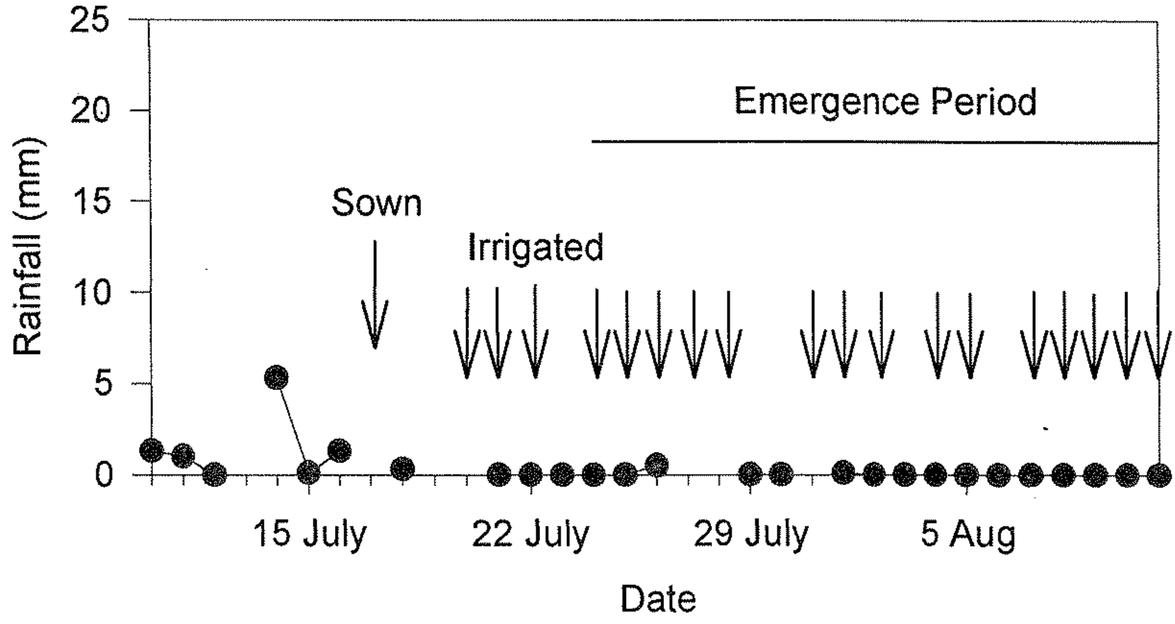


Fig 4

Mean air temperature and rainfall during germination and establishment of crop sown on 17/7/95

Percentage Emergence				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	43.5	47.2	47.2	46.0
Dried Primed	41.0	41.3	39.2	40.5
Fresh Primed	48.4	52.2	52.0	50.9
Mean	44.3	46.9	46.1	

Table 18 Sowing of 17/7/95 - Percentage emergence. LSD (5%,16 df); means of seed treatment or water rate 3.71; within a seed treatment or water rate 8.30; treatments with dissimilar water rates and seed treatments 7.43.

Mean Emergence Time (days)				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	10.5	9.9	10.0	10.1
Dried Primed	8.8	8.8	8.6	8.7
Fresh Primed	7.2	6.9	7.5	7.2
Mean	8.8	8.5	8.7	

Table 19 Sowing of 17/7/95 - Mean emergence time. LSD (5%,16 df); means of seed treatment or water rate 0.39; within a seed treatment or water rate 0.88; treatments with dissimilar water rates and seed treatments 0.79 .

Standard Deviation of Germination Times (days)				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	2.20	1.98	1.66	1.95
Dried Primed	1.83	1.56	1.77	1.72
Fresh Primed	1.53	1.70	1.99	1.74
Mean	1.86	1.75	1.81	

Table 20 Sowing of 17/7/95 - SD of emergence times. LSD (5%,16 df); means of seed treatment or water rate 0.57; within a seed treatment or water rate 1.27; treatments with dissimilar water rates and seed treatments 1.34.

Seedling Weight (g)				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	0.46	0.58	0.47	0.50
Dried Primed	0.52	0.55	0.46	0.51
Fresh Primed	0.70	0.71	0.61	0.67
Mean	0.56	0.61	0.51	

Table 21 Sowing of 17/7/95 - Mean seedling weight. LSD (5%,16 df) for comparing means of seed treatment or water rate 0.06, within a seed treatment or water rate.13, treatments with dissimilar water rates and seed treatments 0.12.

Coefficient of Variation (%)				
	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	52.3	56.8	63.2	57.4
Dried Primed	57.6	62.3	50.3	56.7
Fresh Primed	66.2	56.8	63.4	62.1
Mean	58.7	58.6	59.0	

Table 22 Sowing of 17/7/95 - Coefficient of variation of seedling weight. LSD (5%,16 df) for comparing, means of seed treatment or water rate 8.7, within a seed treatment or water rate 19.5, treatments with dissimilar water rates and seed treatments 17.5.

Sowing of 14/9/95

The rainfall and mean air temperature during germination and establishment are shown in Fig 5. The percentage emergence, mean emergence time and SD of emergence times are shown in Tables 23, 24, and 25, respectively and the mean seedling weight and CV of seedling weights are shown in Tables 26 and 27, respectively. Unless otherwise stated all differences noted below were significant at the 5% level.

In contrast to the first sowing, where water had a beneficial effect, and to the second and third sowings, where the effect of water was broadly neutral, the addition of water in this final sowing appears to have had a detrimental effect on establishment. The percentage emergence of the 8.2 and 18.6 ml/m row water treatments were 59.3 and 59.1 % which was less than the 63.9% achieved by the zero water treatments (Table 23). The corresponding emergence times were 13.4 and 15.0 days compared with 12.7 days for the zero water treatments (Table 24) and the SD of emergence times were 3.13 and 3.72 days compared with the 2.21 for the zero water treatments (Table 25). These results were reflected in the seedling harvest where the mean seedling weight of the zero water treatments (0.115 g) was greater than either the 8.2 ml/m (0.109 g) or the 18.6 ml/m (0.104 g) treatment means (Table 26). There were no effects of water on the CV of seedling weights (Table 27).

The percentage emergence (Table 23) of the fresh primed seed (64.4%) was greater than either that from the dried primed seed (57.6) or the natural seed (60.2%). The ranking of the seed treatments in terms of emergence time was as in the previous experiments with the fresh primed seed being the fastest (11.5 days) followed by the dried primed treatment (13.2 days) and the natural seed (16.4 days) (Table 24). The SD of germination times of the dried primed treatment (2.61 days) was less than that of either the natural (3.35) or the fresh primed seed treatments (3.10) (Table 25). The seedlings from the fresh primed seed (0.121 g) were heavier than those from the dried primed seed (0.111 g) which in turn were heavier than those from the natural seed (0.095 g) (Table 26). However the CV of seedling weights was greater (36.4) than that for dried primed seed (30.9%) or natural seed (29.2%) (Table 27).

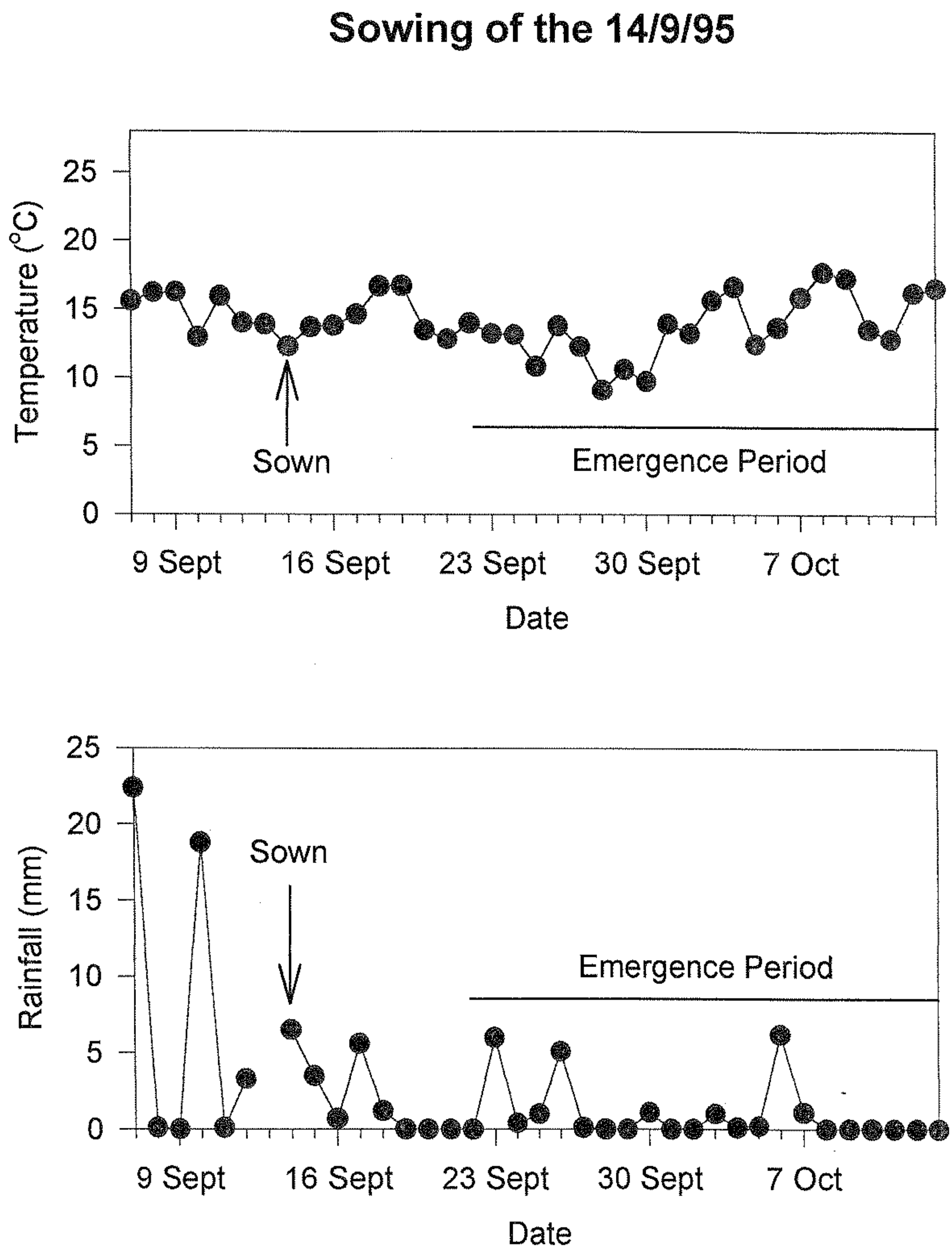


Fig 5

Mean air temperature and rainfall during germination and establishment of crop sown on 14/9/95

Percentage Emergence				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	65.8	53.6	61.2	60.2
Dried Primed	56.7	60.1	56.1	57.6
Fresh Primed	69.2	64.1	59.9	64.4
Mean	63.9	59.3	59.1	

Table 23 Sowing of 14/9/95 - Percentage germination. LSD (5%,16 df); means of seed treatment or water rate 2.89; within a seed treatment or water rate 6.46; treatments with dissimilar water rates and seed treatments 5.78.

Mean Emergence Time (days)				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	15.8	15.9	17.6	16.4
Dried Primed	12.4	12.8	14.2	13.2
Fresh Primed	9.9	11.5	13.1	11.5
Mean	12.7	13.4	15.0	

Table 24 Sowing of 14/9/95 - Mean emergence time. LSD (5%,16 df); means of seed treatment or water rate 0.33; within a seed treatment or water rate 0.75; treatments with dissimilar water rates and seed treatments 0.67.

Standard Deviation of Germination Times (days)				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	3.10	3.16	3.81	3.35
Dried Primed	1.82	2.69	3.31	2.61
Fresh Primed	1.72	3.55	4.03	3.10
Mean	2.21	3.13	3.72	

Table 25 Sowing of 14/9/95 - SD of emergence times. LSD (5%,16 df), means of seed treatment or water rate 0.30; within a seed treatment or water rate 0.68; treatments with dissimilar water rates and seed treatments 0.61.

Mean Seedling Weight (g)				
Seed treatment	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	0.104	0.095	0.087	0.095
Dried Primed	0.118	0.113	0.103	0.111
Fresh Primed	0.123	0.120	0.121	0.121
Mean	0.115	0.109	0.104	

Table 26 Sowing of 14/9/95 - Mean seedling weight. LSD (5%,16 df) for comparing means of seed treatment or water rate 0.005, within a seed treatment or water rate 0.012, treatments with dissimilar water rates and seed treatments 0.011.

Coefficient of Variation (%)				
	Water rate (ml/m row)			
	0	8.2	18.6	Mean
Natural	28.9	28.2	30.5	29.2
Dried Primed	27.1	33.3	32.4	30.9
Fresh Primed	36.1	38.7	34.5	36.4
Mean	30.7	33.4	32.5	

Table 27 Sowing of 14/9/95 - Coefficient of variation of seedling weight. LSD (5%,16 df) for comparing, means of seed treatment or water rate 3.99, within a seed treatment or water rate 8.92, treatments with dissimilar water rates and seed treatments 7.98.

EXPERIMENTS WITH FRESH PRIMED SEED - 1996

Materials and Methods

Two experiments (sown on 18 March and 24 April) were carried out in the Spring of 1996 on commercial salad onion crops grown by J.J Barker Ltd near Southfleet, Gravesend, Kent. The crop was drilled with a standard "Miniair" drill and hence it was not possible to add water to the seed from the drill as had been done in the 1995 experiments. The nominal seed rates were 36 seed/ft (118 seed/m) for the first sowing and 30 seeds/ft (98 seeds/m) for the second. The seed treatments were again natural, fresh and dried primed seed.

Each of the five replicates consisted of a 22m portion of a 5-row bed. The outer rows of the bed were guard rows, the centre row was always natural seed and the two priming treatments were allocated randomly to rows number 2 and 4. In the first sowing a 10m portion of each bed was covered with polythene and another 10m portion was not covered.

During the first sowing seedling emergence counts were made at 2-day intervals. For both sowings, when the crops were ready to harvest (first sowing 4 July, second sowing 18 July) a 2m portion of row was removed and weighed.

Sowing of 18/3/96

The increase in the number of emerged seedlings per metre of row (Table 28) associated with covering with polythene was not significant. However more seedlings emerged from dried primed seed than from either the natural or the fresh primed seed. Although the drill was set up very carefully, it is possible that under the commercial conditions of the experiment, at least some of this difference might be due to small difference in the number of seeds delivered by the seed metering units. Any such differences would not affect the mean emergence times (Table 29). Covering natural seed reduced mean emergence times from 32.4 to 25.2 days. The effect of priming was slightly smaller, reducing the emergence times of the dried and fresh primed seed to 27.8 and 26.2 days, respectively. As might be expected the combined effect of covering and priming was greater than the effect of either treatment alone, and they were almost additive. For example the use of fresh primed seed reduced emergence times by 6.2 days, covering reduced it by 7.2 days, while both treatments together reduced it by 12.2 days. Both priming and covering tended to increase the standard deviation of germination times (Table 30). This is probably because both treatments were more effective at increasing the speed of emergence of the vigorous seeds than they were the less vigorous seeds.

The effect of covering and priming on seedling emergence times was reflected in the weight of the crop at harvest. Table 31 shows that covering natural seed increased the fresh weight per metre of row from 355 to 473 g, whereas priming increased it to 450 for the dried and 440 for the fresh primed seed. However the combined effect of priming and covering was to increase the yield to 533 g per metre of row.

Seedlings per m of row			
	Bare	Covered	Mean
Natural	76.9	80.3	78.6
Dried	88.0	91.6	89.5
Fresh	76.7	86.4	81.7
Mean	80.5	86.1	

Table 28 Sowing of the 18/3/96 - Seedlings per m of row. LSD (5%), between seed treatment means 5.2(16df); between covering treatment means 7.3(4df); between seed treatments with the same covering treatment 7.3(16df); between seed treatments with different covering treatments 8.2 (13df).

Mean Emergence Time (days)			
	Bare	Covered	Mean
Natural	32.4	25.2	28.8
Dried	27.8	21.2	24.5
Fresh	26.2	20.2	23.2
Mean	28.8	22.2	

Table 29 Sowing of 18/3/96 - Mean emergence time. LSD's (5%), between seed treatment means 0.65(16df); between covering treatment means 0.82(4df); between seed treatments with the same covering treatment 0.92(16df); between seed treatments with different covering treatments 0.98 (15df).

Standard Deviation of Germination Times (days)			
	Bare	Covered	Mean
Natural	1.93	2.50	2.21
Dried	2.61	2.69	2.65
Fresh	2.98	3.05	3.01
Mean	2.51	2.74	

Table 30 Sowing of 18/3/96 - Standard Deviation of germination times. LSD (5%), between seed treatment means 0.47 (16df); between covering treatment means 0.34 (4df); between seed treatments with the same covering treatment 0.67 (16df); between seed treatments with different covering treatments 0.59 (20df).

Fresh Weight per m of row (g)			
	Bare	Covered	Mean
Natural	355	473	414
Dried	450	564	511
Fresh	440	561	501
Mean	418	533	

Table 31 Sowing of the 18/3/96 - Fresh weight of crop per metre of row. LSD (5%), between seed treatment means 51(16df); between covering treatment means 88(4df); between seed treatments with the same covering treatment 72(16df); between seed treatments with different covering treatments 94 (10df).

Sowing of the 24/4/96

The mean yield of the natural seed was 569 grams per metre of row. (Table 32). The use of fresh and dried primed seed increased this to 842 and 815 g/m respectively. The difference between the two priming treatments was not significant.

Weight per m of row(g)	
	Bare
Natural	569
Dried	815
Fresh	842

Table 32 Sowing of the 24/4/96 - Fresh weight of crop per metre of row. LSD (5%, 18df) for differences between treatments 149.

CONCLUSIONS

Two main questions needed to be addressed at the start of this project. Firstly, given the expected short shelf life and delicate nature of fresh primed seed, can it be stored for a sufficient period and drilled with conventional seed drills? Secondly, even if storage and drilling are not a problem, are the additional benefits (compared with conventionally primed and dried seeds) worth the additional difficulties of using fresh primed seed?

No significant deleterious changes in germination (radicle emergence) could be detected in fresh primed seed stored at either 5°C or 15°C for up to 30 days. In fact, stored fresh primed seed tended to germinate faster than seed which had not been stored, presumably because further priming occurred during the storage period. In seedling evaluation tests, there was no effect on the weight of seedling grown from seed stored for up to 30 days. However, after 25 days of storage at either temperature, there was a reduction in the length of the seedling roots, and at 15°C only there was an effect on the percentage of abnormal seedling. No difficulty was experienced when using fresh primed seed with either of the two types of commercial seed drill used in the field experiments. On this limited evidence therefore it would seem that, if kept cool, fresh primed seed can be stored for up to three weeks, and can be drilled without any problems.

The question of any advantage over normal primed seed is more complex. For fresh primed seed to show their full potential it is logical to assume that they need to be placed in a moist environment to enable rapid germination. Otherwise if allowed to dry before germinating they loose the advantage of their high water content and simply become conventionally primed and dried seed. The addition of water from the seed drill in 1995 was an attempt to ensure that the fresh primed seed did not dry out. The addition of water in the first sowing (22/3/95) increased the percentage emergence, reduced the mean emergence times and reduced the standard deviation of emergence times. However in the second and third sowing the effects were broadly neutral, and in the fourth it was detrimental. These results are difficult to explain but it is possible that water added from the drill during the first sowing, when evaporative conditions were less severe, was more effective than that added in subsequent sowings. However the effect of adding water was not such that it can be recommended as a general practice. An alternative method of maintaining moisture in the seedbed is to cover it with polythene, and this was used for the 1996 experiment. The following discussion concerns only seed sown without the addition of water from the seed drill.

The four advantages that a grower might hope to obtain from the use of fresh primed seed are: an increase in the percentage emergence, an increase in crop uniformity, more rapid crop emergence, and an increase in plant weight.

There were no consistent effects of the priming treatments on the percentage emergence in 1995 or number of plants per metre of row in 1996. Similarly there were no significant effects of the treatments on the CV of seedling weight on any occasion in 1995. The effects on SD of emergence times showed also showed no consistent trend.

	Emergence time as % of that for natural seed					
Sowing date	22/3/95	5/4/95	1/5/95	23/3/95	18/3/96B	18/3/96C
Dried primed	82	84	84	78	86	84
Fresh primed	75	73	69	63	81	80

Table 33 Emergence time as a percentage of that of natural seed, for primed treatments drilled without water. B = Bare (not covered), C = Covered.

	Increase in seedling weight as % of seedlings from natural seed			
Sowing date	22/3/95	5/4/95	1/5/95	23/5/95
Dried primed	NS	NS	NS	13
Fresh primed	43	42	52	18

Table 34 Seedling weight as a percentage of seedling from natural seed for primed treatment drilled without water.

The most striking effects of fresh primed seed were on seedling emergence times and on seedling (or crop) weight. Table 33 shows that dried primed seed consistently emerged before natural seed and that fresh primed seed consistently (and statistically significantly) emerged before dried primed seed. In 1995, fresh primed seed consistently produced heavier seedlings (Table 34). In 1996 there was little difference between the harvest weight of crops grown from fresh or dried primed seed (see Tables 31 and 32), although both were heavier than that from natural seed.

From the experiments described in this report, it can be concluded that the use of fresh primed seed does not produce a consistent increase in seedling uniformity compared with either natural or dried primed seed. However, in early drillings crops grown from fresh primed seed emerge 1.5 to 2 days earlier than those from dried primed seed, and up to a week earlier than natural seed. The use of primed seed (fresh or dried) increased the harvest weight of crops by an average of 22% (Table 31) and 45% (Table 32) but there was little difference between the two priming treatments.

The value of fresh primed seed is a commercial rather than a scientific judgement, but there seems little doubt that for salad onions there is little to be gained from using fresh, rather than dried primed seed. It is possible that fresh primed seed could have a value in situations where there are problems with establishment and where the seed can be prevented from drying.

REFERENCES

Anon (1979) ISTA Handbook for seedling evaluation. 2nd Ed. J. Bekendam, R. Grob

Buljalski, W., Nienow, A. W. and Gray, D. (1989) Establishing the large scale osmotic priming of onion seeds by using enriched air. *Annals of Applied Biology* **115,** 171-176.

Buljalski, W. and Nienow, A. W. (1991) Large-scale osmotic priming of onion seeds: a comparison of different strategies for oxygenation. *Scientia Horticulturae* **46,** 13-24.

Gray, D. and Steckel, J. R. A. (1983) A comparison of methods for evaluating seed quality in carrots (*Daucus carota*) *Annuls of Applied Biology* **103** 327-334.

Heydecker, W., Higgins, J. and Gullivar, R. J. (1973) Accelerated germination by osmotic seed treatment. *Nature* **246** 42-44.

Rowse, H. R., Costigan, P. A. & Thompson, A. R. (1988). Sub-seed injection of fertilisers and pesticides - equipment and preliminary results. In *Proceedings of the 11th Conf. Int Soil & Tillage Res. Org. (ISTRO),* Edinburgh, UK pp 845-50.

Rowse, H. R. (1991) Methods of priming seeds. *UK Patent No 2192781.*

Rowse, H. R. (1993) Design and testing of commercial prototype equipment for the application of starter fertilizer. *Final report, HDC project No. FV41a.* 18 pp.

Rowse, H. R. (1994) Seed priming. *UK Patent Application No 9418763.0 16 Sept 1994.*

Rowse, H. R. (1996) Drum Priming - A non-osmotic method of priming seeds. *Seed Science and Technology* (In press).

Stone, D. A. and Rowse, H. R. (1992) Reducing the nitrogen requirement of vegetable crops by precision fertilizer injection. In *Aspects of Applied Biology 30. Nitrate and Farming Systems*, pp 399-402.

Stone D. A. and Rowse, H. R. (1995) Starter fertilizer for drilled horticultural crops. *Final Report, HDC Project No. FV41.*

Whitfield W. A. D. (1974) The soils of the National Vegetable Research Station, Wellesbourne. *Annual Report of the National Vegetable Research Station for 1973.* pp 21-30.

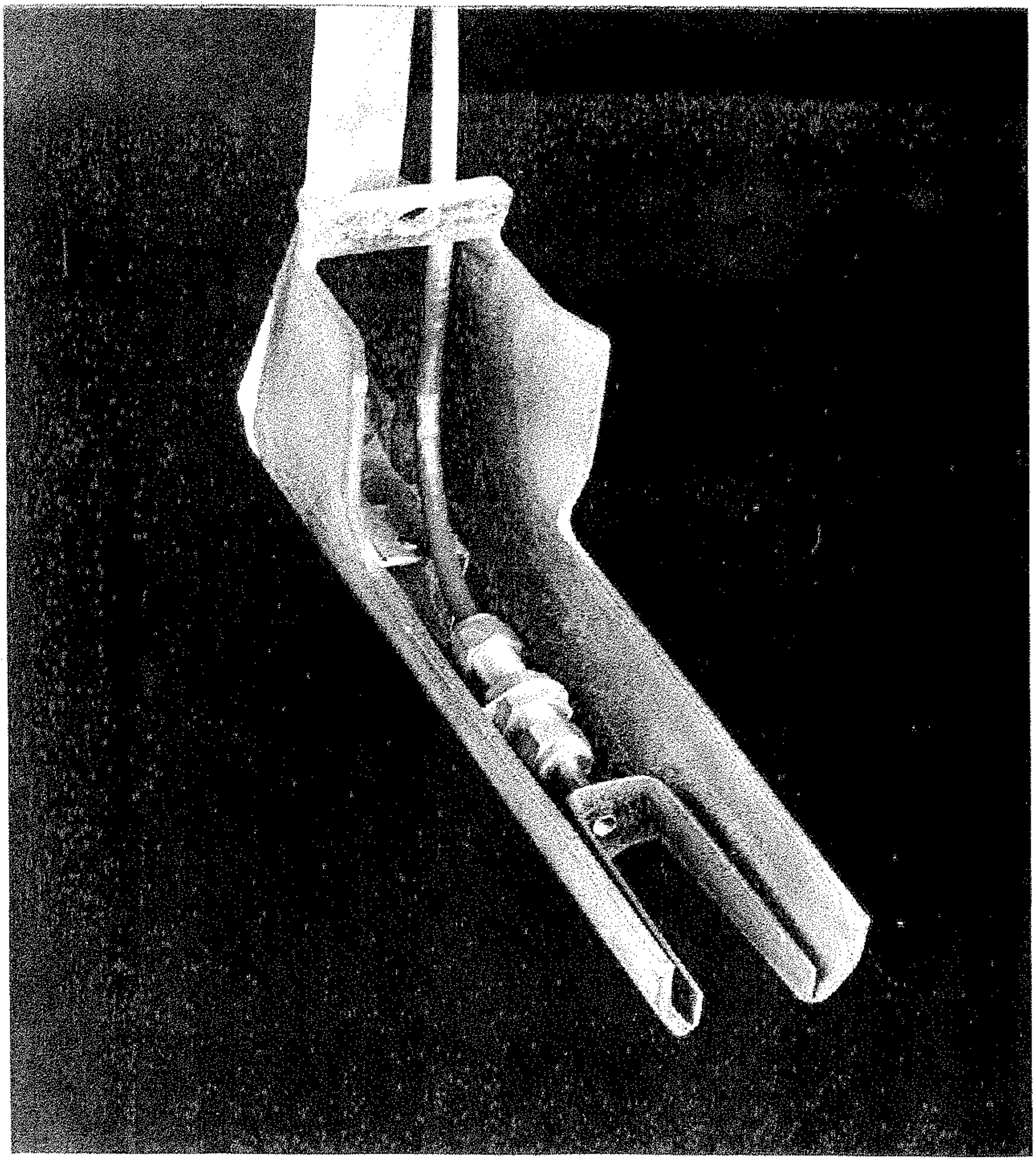


Fig 1 Stanhay S870 seed coulter modified to inject water into seed furrow.

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Fig 2 Mean air temperature and rainfall during germination and establishment of crop sown on 22/3/95.

Fig 3 Mean air temperature and rainfall during germination and establishment of crop sown on 19/5/ 95.

Fig 4 Mean air temperature and rainfall during germination and establishment of crop sown on 17/7/ 95.

Fig 5 Mean air temperature and rainfall during germination and establishment of crop sown on 14/9/ 95.