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GREEN PANIC ESTABLISHMENT AS INFLUENCED BY STRAW MULCH AND MOISTURE

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SUMMARY

Field emergence and viability of residual seed of green panic (*Panicum maximum* var. *trichoglume* cv. Petrie) were observed at Gayndah with various amounts of irrigation and rainfall after sowing at 1 cm in a self-mulching clay beneath a straw mulch applied at 0, 2 500 and 5 000 kg/ha.

Mulch improved emergence, with an increase from less than 0·4% in bare soil to 2–13% with mulch at 5 000 kg/ha after 40 mm irrigation. An increase in emergence with increasing amounts of irrigation up to 30 mm was greater in mulched soil than in bare soil. Additional rain caused extra emergence and the amount of viable residual seed was inversely related to field emergence.

Mulch reduced soil drying rate, diurnal variation of moisture in the seed zone and soil crusting compared with bare soil. Equations on soil/atmospheric temperature relationships are presented.

Reliability of establishment with mulch is discussed.

I. INTRODUCTION

Low reliability of establishing fine-seeded grasses in self-mulching soil west of the coastal ranges in Queensland is a feature of conventional sowing methods described by Wilson (1956). Low percentage establishment of viable seed sown is an associated feature. Sowing into dry soil is common because of the necessity to sow shallow, the large areas involved and the limitations of sowing machinery in wet soil. Seedling emergence with this practice is dependent on subsequent rain, with good rains over several days being most effective. Emergence failures commonly result from small rainfalls followed by rapid soil drying causing seed spoilage and by the development of a dry crumb-crust complex at the soil surface impeding emergence (Leslie 1965).

Sowing beneath a mulch of crop residues improved emergence of green panic (*Panicum maximum* var. *trichoglume* cv. Petrie) compared with sowing into bare soil (Rickert 1973). This was largely attributed to a reduced drying rate in the seed zone. This paper details soil moisture changes in mulched and bare soil and reports the establishment and amount of viable residual seed under different moisture regimes and sowing times.

II. MATERIALS AND METHODS

Seven small plot field experiments (Table 1) were conducted at "Brian Pastures" Pasture Research Station near Gayndah (25° 38′ S., 151° 41′ E.). Surface mulches of chaffed native pasture were applied at 0, 2 500 or 5 000 kg/ha (M_0, M_1 and M_2 respectively) in factorial combinations with a single irrigation of 10, 20, 30 or 40 mm (experiments 1 to 5) or rainfall alone (experiments 6 and 7).

Experiments 1 to 5 were conducted sequentially on the same site using four wooden frames each 4·5 m long x 3·0 m wide x 25 cm deep. Each frame contained six separate compartments or plots of 1·5 m x 1·5 m. There were two replications (each of two frames giving 12 plots) of the three rates of mulch and four rates of irrigation. An additional wooden frame was used for experiments 6 and 7; each of these consisted of three replications of the M_0 and M_2 treatments.

The wooden frames were embedded in the soil with their upper edges level with the outside soil surface. Each compartment was then filled with 23 cm of self-mulching soil (sand 27%, silt 21%, clay 52%, field capacity (0·33 atm) 35%, and wilting point (15 atm) 21% by weight).

The 2 cm freeboard between the soil level within the wooden frame compartments and the soil outside served to prevent run-off of water and to anchor the mulch.

Two or four steel frames (experiments 1 to 5 and 6 and 7 respectively), each of 50 cm length x 10 cm width x 2·5 cm depth, were embedded in each compartment with their upper edges level with the soil surface. Each frame stood on a 3 mm mesh nylon net 55 cm long x 15 cm wide which was previously positioned by excavation. Sufficient soil was then replaced on the net within the frame to bring the level to 1 cm below the upper edge. After broadcasting 1 000 seeds within each frame the remaining soil was added to bring the final soil level flush with the upper edge of the frame (and the soil outside) (see Figure 1).

Eight copper constantan thermocouples (24 gauge) were connected in parallel and installed (four to each replicate) at 10 mm depth in the plots receiving 30 mm irrigation; the mean temperature was measured by a multi-channel potentiometric recorder with inbuilt reference junction.

After applying mulch to the appropriate plots, irrigation was applied to experiments 1 to 5 in 10 mm increments by a hand-operated rose spray connected through a water meter delivering 8 litres/min. Increments were applied rotationally so as to commence and finish irrigating a replication on plots receiving 40 mm. For each experiment the irrigation was completed by 1300 hr on the dates indicated in Table 1.

A clear polythene tent was erected over each wooden frame when rain threatened and removed when rain cleared, to ensure that soil drying occurred without rewetting. Tents were open each end to facilitate ventilation.

With the exception of experiment 1, soil moisture percentage was determined for the 0–1, 1–2, 2–5, 5–10, 10–15 and 15–23 cm horizons at 1–3 day intervals after irrigation. Samples were collected by 1100 hr and dried for 24 hr at 105°C.

Seedlings were counted and removed from each frame 21 days after the initial wetting. An extra count was made in experiments 6 and 7. Seed and soil in the frame were collected by lifting the nylon net, and by a system of sieving and winnowing the seed was retained in the soil reduced to a volume of 150 c.c. Each sample was transferred to a 10 cm x 13 cm tray with a perspex lid, wet with 90 c.c. of rain water and held in a dark germinator at 20/30°C (16/8 hr) alternating temperature regime. Soil was kept moist and germinations were counted regularly from day 3 with a final count at day 21.

After each experiment the mulch was raked off and the plots were hand-cultivated to 10 cm. An irrigation of 25 mm was applied to remove treatment effect before the next experiment commenced. Plots were not shielded from rain between experiments.

Commercial green panic seed was used in all experiments. This was cleaned to 99% purity by weight and stored from December 1970 in sealed polythene bags each of 500 g capacity. One bag was opened for sowing each experiment and the excess seed discarded. By June 1972, the cumulative germination of the stored seed on a moist towel substrate was:—day 2, 0%; 3, 1·4%; 5, 4·8%; 7, 10·1%; 10, 19·4%; 14, 24·9%, and 21, 28·5%.

Ant activity was checked by spraying with 0·4% dieldrin before each sowing.

III. RESULTS

Climatic data.—Conditions were coolest for experiment 2 and warmest for experiment 4 (Table 1). Daily evaporation for days 1 to 7 did not exceed 8 mm and mean daily evaporation for the period was less than 5·5 mm.

TABLE 1

SEED QUALITY AND CLIMATIC DATA FOR EXPERIMENTS 1 TO 7

Experiment Number	Date of Commencement	Germinability of Seed at 21 Days (%)*	Mean Daily Climatic Data for Days 1 to 7		
			Screen Temperature (°C)		Free Water† Evaporation (mm)
			Maximum	Minimum	
1	22.iv.71	38	33·8	13·6	3·6
2	28.vii.71	43	25·8	5·1	3·5
3	15.x.71	46	29·2	13·1	5·4
4	10.i.72	41	31·1	21·3	5·3
5	29.ii.72	30	30·5	19·6	4·7
6	25.xi.71	42	30·5	16·9	5·4
7	14.i.72	41	31·5	21·1	4·7

* As determined by D.P.I. seed testing laboratory, Indooroopilly.

† Obtained from an Australian tank fitted with a float gauge.

Field emergence.—Emergence increased with increasing amount of irrigation and mulch in experiments 1 to 5 (Figure 1). Emergence was not evident after an irrigation of 10 mm except in experiment 5, where 0, 0·04 and 0·22% (not present in Figure 1) of seed sown emerged in M_0, M_1 and M_2 respectively. Usually emergence with either M_1 or M_2 was not significantly increased with the increase in irrigation from 30 to 40 mm. Emergence with M_0 was less than 0·4% after all irrigations. Low temperatures contributed to the overall low emergence in experiment 2.

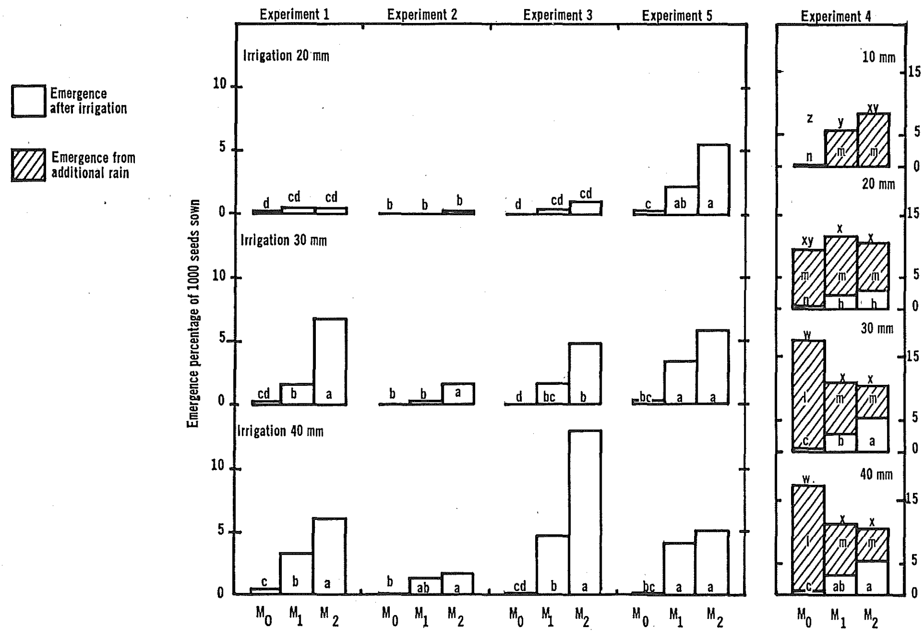


Fig. 1.—Field emergency after irrigation and rainfall in experiments 1 to 5. In each experiment, columns not containing the same letter differ ($P < 0{\cdot}05$).

On day 13 of experiment 4, strong winds preceding a thunderstorm severely damaged the polythene tents and prevented their re-erection. Rain additional to irrigation in this experiment totalled 29 mm over 5 of the 8 remaining days. Extra emergence was greatest in the M_0 that previously received 30 or 40 mm irrigation and least in M_0 that received 10 mm (Figure 1).

In experiment 6 field emergence at the first count on day 21 was greater with M_2 than with M_0 after a total rainfall of 34 mm over 5 wet days (Figure 2). When the experiment was terminated on day 27, after an additional 42 mm, extra emergence was also greater in M_2 than in M_0. In experiment 7, emergence at the first count on day 10 after 96 mm over 8 wet days was also superior in M_2. After an additional 28 mm and when the experiment was terminated on day 21, extra emergence was similar in both treatments.

Germination of residual seed.—Interactions between amounts of mulch and irrigation on germination of residual seed were not evident. Mulch did not consistently influence germination at day 3 and reductions after 10 mm irrigation were not evident at day 21 (Table 2). Rain in experiment 4 drastically reduced germination of residual seed, which was greatest in M_0 and after 10 mm irrigation.

In experiments 6 and 7, germination of residual seed at days 3 and 21 was greater in M_0 than in M_2 (Figure 2).

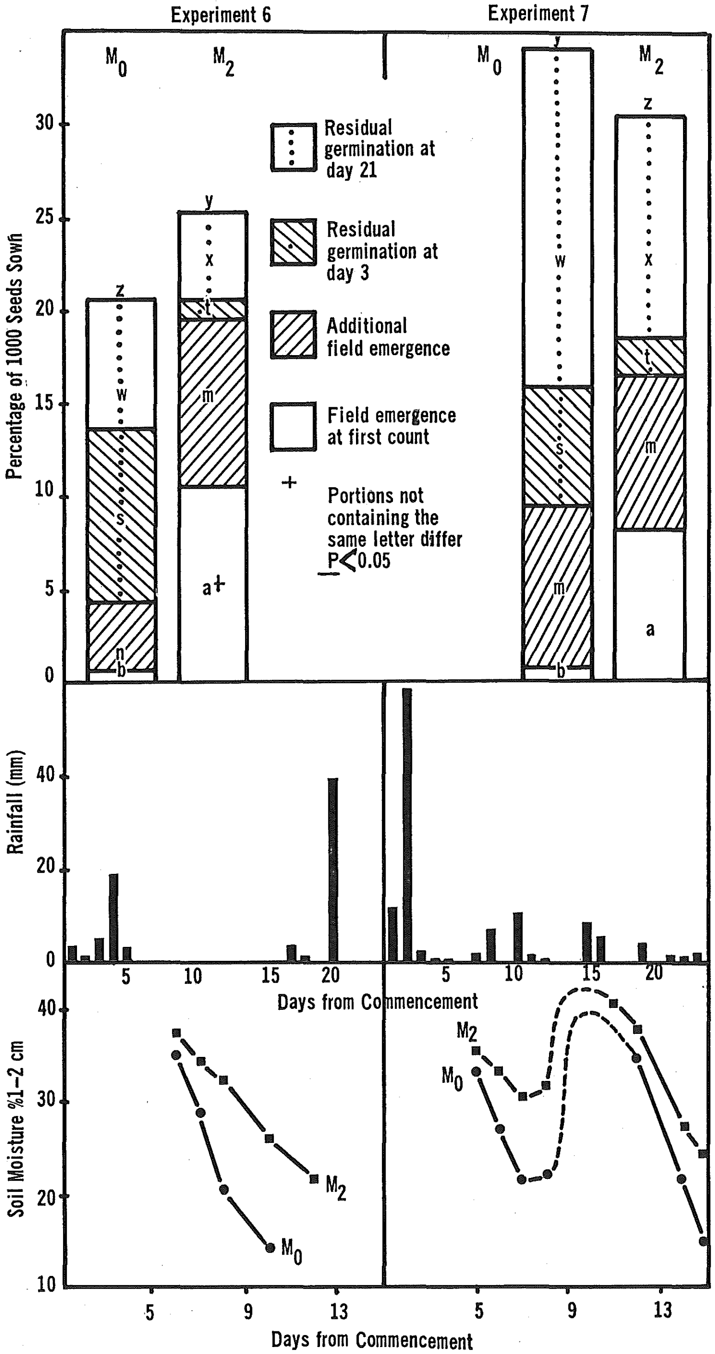


Fig. 2.—Rainfall and the resulting soil moisture, field emergence and residual viability in experiments 6 and 7. In each experiment, columns not containing the same letter differ ($P < 0{\cdot}05$).

TABLE 2

Residual and Total Germination
Equivalent % of original 1 000 seeds sown

Observation	Exp. No.	Irrigation (mm)				Mulch		
		10	20	30	40	M_0	M_1	M_2
Residual germination at 3 days†	1	12·3 b*	19·0 a	22·7 a	21·6 a	20·8 x	21·5 x	14·1 y
	2	6·6 b	21·5 a	25·1 a	25·4 a	14·4 y	22·6 x	19·9 xy
	3	6·0 c	13·8 b	18·3 ab	19·4 a	12·2 x	16·6 x	13·0 x
	4	5·8 a	2·0 b	1·1 b	1·5 b	4·2 x	2·2 y	1·1 y
	5	4·7 b	10·5 a	15·0 a	13·3 a	7·3 y	13·6 x	11·1 xy
Residual germination at 21 days†	1	47·3 a	37·0 b	34·1 b	33·2 b	45·1 x	39·2 x	29·5 y
	2	40·6 a	40·4 a	40·6 a	40·5 a	40·1 x	41·3 x	40·1 x
	3	40·8 a	38·1 a	39·7 a	34·1 a	42·4 x	38·9 x	33·2 y
	4	15·1 a	8·1 b	5·5 b	5·2 b	11·9 x	8·8 xy	4·5 y
	5	25·2 a	31·6 a	33·5 a	32·4 a	30·4 x	33·9 x	27·6 x
Total germination (= field emergence + residual germination)†	1	47·3 a	37·2 a	37·2 a	36·8 a	45·2 x	40·7 xy	33·1 y
	2	40·6 a	40·5 a	41·4 a	41·7 a	40·2 x	41·8 x	41·1 x
	3	40·8 a	38·5 a	41·9 a	40·5 a	42·4 x	40·7 x	38·3 x
	4	20·8 a	19·2 a	18·4 a	18·1 a	24·2 x	19·1 xy	14·6 y
	5	25·6 b	34·8 a	36·7 a	35·9 a	30·6 x	36·5 x	32·1 x

† Values as equivalent means of inverse sine transformations.
* Values not followed by the same letter in each experiment differ $P < 0{\cdot}05$.

Total germination.—Seed spoilage, indicated by reduced total germination, was unaffected by irrigation in experiments 1 to 5 (Table 2 and Figure 2). Substantial field emergence accompanied the seed spoilage evident in M_2 compared with M_0 in experiments 1, 4 and 7. Experiment 6 was to the contrary. In experiments 2, 3 and 5 mulch did not influence total germination.

Soil moisture.—Experiment 5 (Figure 3) typifies profile soil moisture changes after irrigation in experiments 2 to 5. On the morning after irrigation, moisture accumulated in the 0–2 cm horizon and this was directly related to the amount of mulch and irrigation. A progressive decline followed and the accumulation was seldom evident on the morning of day 3. Soil drying was largely restricted to the 0–5 cm horizon.

Within the 1–2 cm horizon observed soil moisture percentage (y) was linearly related to days from wetting (x) as indicated by experiment 6 (Figure 2). Such regressions were determined for individual treatments of each replication in experiments 2 to 5 and solved for x when y equalled 21%. This estimated drying time increased with increasing rates of mulch and irrigation but not with M_2 from 30 to 40 mm (Figure 4).

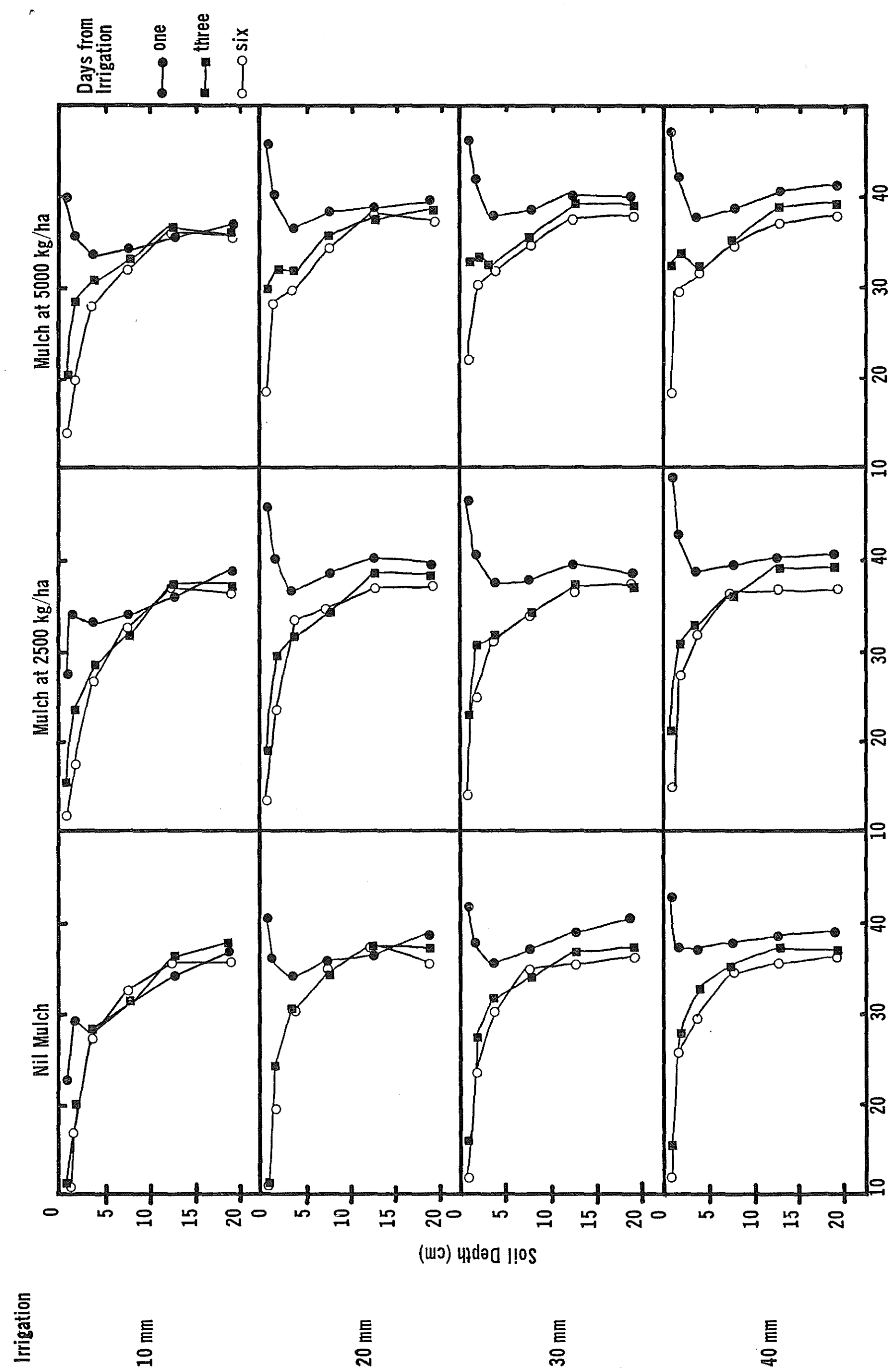


Fig. 3.—Changes in the soil moisture profile during 6 days after irrigation (experiment 5).

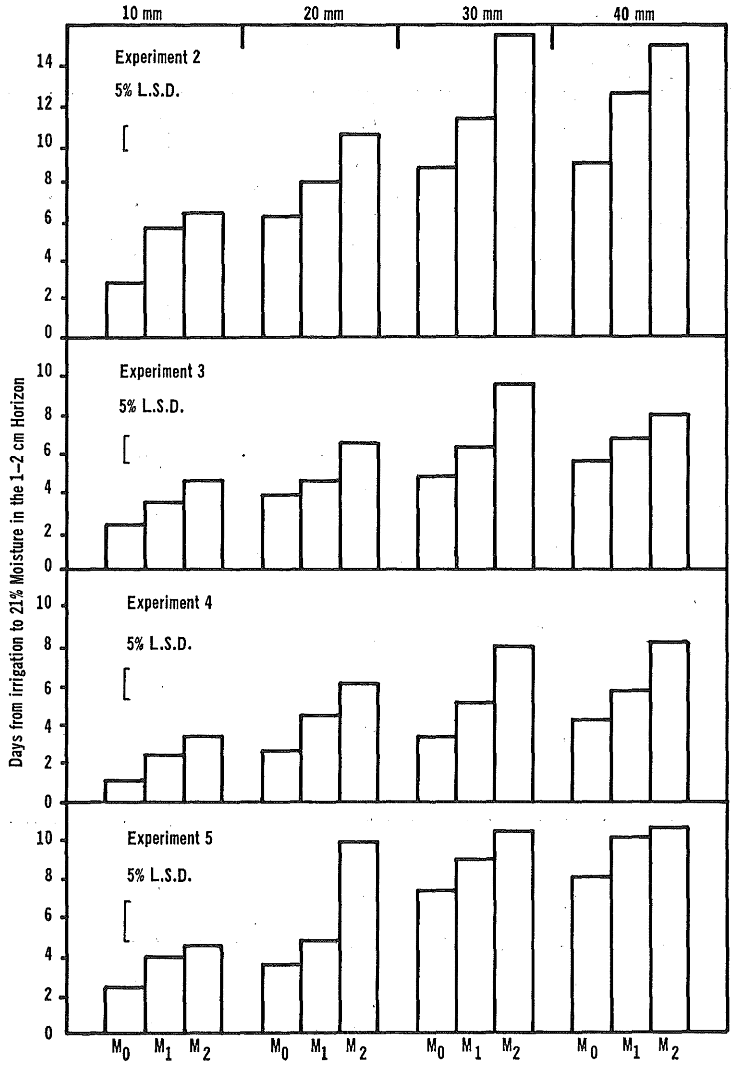


Fig. 4.—Soil drying time after irrigation.

Soil temperature.—Typical diurnal trends were evident, with the daily maximum less and the daily minimum greater in mulched soil than in bare soil.

Soil temperatures at 1 cm were positively related to atmospheric temperature and negatively related to the soil moisture content in the 1–2 cm horizon. (Table 3). The influence of soil moisture was less evident at the 0900 hr observation than the influence of maximum or minimum temperatures.

Soil crusting.—In all experiments soil crusting at the surface was reduced with increasing rate of mulch (Figure 5).

B

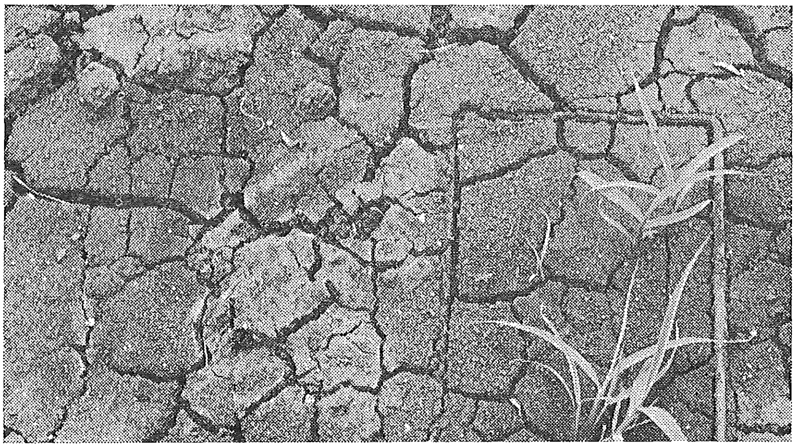
TABLE 3

COEFFICIENTS FOR LINEAR REGRESSIONS OF THE FORM $z = a + bx + cy$, RELATING SOIL TEMPERATURE AT 1 cm (z) TO ATMOSPHERIC SCREEN TEMPERATURE (x) AND SOIL MOISTURE CONTENT (y)*

Temperature Observation (°C)	M_0				M_1				M_2			
	a	b	c	r^2	a	b	c	r^2	a	b	c	r^2
Maximum	7·98	1·29++	−0·38++	0·73	10·13	1·07++	−0·31+	0·64	9·16	1·01++	−0·29+	0·64
Minimum	8·11	0·89++	−0·16++	0·96	8·44	0·84++	−0·10+	0·95	9·42	0·81++	−0·08	0·94
$\frac{\text{Max.} + \text{Min.}}{2}$	8·99	1·12++	−0·27++	0·92	6·87	1·07++	−0·18+	0·88	6·16	1·04++	−0·15+	0·89
9 a.m.	4·69	1·13++	−0·16	0·82	0·05	1·18++	−0·10	0·92	1·49	1·12++	−0·12+	0·92

Probability ratings:— $++P<0·01$; $+P<0·05$.

* Since x and y are independent we can use the coefficients from the multiple regression equation when considering the effect of x alone on z (when y is kept constant) and y alone on z (when x is kept constant).



a

b

c

Fig. 5.—Soil crusting as influenced by amount of mulch 21 days after an irrigation of 40 mm in experiment 3: (a) bare soil, (b) mulch at 2 500 kg/ha, (c) mulch at 5 000 kg/ha. The mulch was removed from the soil surface adjacent to a steel sowing frame.

IV. DISCUSSION

Effects of mulching.—Compared with bare soil, mulching reduced the rate of soil drying. In addition, the 0–2 cm horizon under a mulch exhibited less diurnal variation in moisture content (unpublished data) and a more pronounced accumulation of moisture on the morning of the first to third day after irrigation. Such moisture conditions favoured both seed germination and emergence, as increasing moisture stress reduces the rate and amount of germination (McWilliam and Phillips 1971) and also plumule and radicle extension (Knipe and Herbel 1960).

Seedling emergence was also enhanced by less impedance from the surface crust in mulched soil compared to bare soil (Arndt 1965; Smith 1966). Interception of light by the mulch, thereby restricting pre-emergent development of primary leaves in seedlings, may have also reduced the incidence of dry crumbs preventing emergence (Leslie 1965).

Germination of residual seed at 3 days was greater than the 1·4% obtained at day 3 in stored seed, indicating a stimulation to germination by wetting and drying seed in the soil. Leslie (1970) reported that after a critical exposure period such a stimulatory effect was produced equally by a substantial range of wet periods. Also germinability was reduced accordingly when seed germinated during a wet period. This occurred in experiment 4 and with M_2 in other experiments of this paper. Less germination at day 3 after 10 mm of irrigation indicates that moist conditions were not of sufficient duration to cause the same stimulatory effect as other irrigation treatments.

Reliability of establishment.—Sowing green panic at different times beneath straw mulch at rates of 2 500 to 5 000 kg/ha has consistently resulted in superior emergence to sowing into bare soil (Rickert 1971, 1973). This suggests that mulching offers improvement in the percentage of seed established.

A sowing technique which improves establishment from small falls of rain should also improve overall reliability of establishment. Provided establishment is adequate, this superiority need not be evident when favourable moisture conditions prevail. Reliability of a sowing technique is indicated by considering field emergence and seed spoilage or alternatively seed remaining viable and post-emergence seedling survival under a range of environments. Seed quality influences reliability, as the degree of seed spoilage depends on rate of seed germination in relation to rate of soil drying. Provided some residual seed remains viable after an emergence failure, establishment may result from subsequent rain.

Irrigations of 10 mm with straw mulch applied up to 5 000 kg/ha neither resulted in effective green panic emergence nor caused significant seed spoilage relative to other amounts of irrigation. With smaller amounts of irrigation and presumably rainfall, a similar result would be expected. When substantial rainfalls followed 10 mm irrigation (experiment 4) emergence was greater and viable residual seed less in mulched soil than in bare soil. With less follow-up rain a lower order of these results would be expected. It appears unlikely that amount and distribution of rainfall would be such as to cause seed spoilage without emergence in mulched soil but not in bare soil.

Basic to the above consideration is the use of seed exhibiting a relatively slow rate of increase in cumulative germination while favourable conditions for establishment prevail. When soil drying is rapid some seed spoilage may result but viable seed remains. Seed lines which germinate completely within a few days of wetting may spoil after a small fall of rain. However, such lines could be suited for sowing into wet soil. Blending seed lines differing in rate of germination may enhance reliability of establishment with a given sowing technique once the optimum type of germination for the technique is defined.

Field emergence after sowing beneath a mulch is also superior to sowing into bare soil when favourable conditions prevail (experiments 6 and 7 of this paper and experiment 1 of Rickert (1973)). This is associated with less viable seed remaining in mulched soil than in bare soil. However, the latter only assumes importance if seedling survival from the initial emergence is low.

Post-emergence seedling survival is enhanced by good subsoil moisture at sowing, post-emergence rain and reduced interplant competition (Leslie 1965; Campbell 1969). In this regard mulched soil compared with bare soil has superior water infiltration and a reduced rate of evaporation (McCalla and Army 1961) and less weed growth (Rickert 1973). Experiment 2 of Rickert (1973) was relatively long term and 82 days without effective rain followed the initial irrigation. After this period trends in seedling density were similar to those evident soon after irrigation, indicating that seedling survival with mulched soil in dry conditions was not inferior to that in bare soil. However, frosting may cause seedling mortalities (Jones 1969) and this is more severe over mulched soil than over bare soil. Minimum air temperature 1 cm above the surface of M_0, M_1 and M_3 was —0·8, —1·4 and —2·4°C on day 17 of experiment 2, when the screen minimum was 0·7°C.

Together these results suggest that sowing beneath a straw mulch offers improved reliability of establishment of green panic in a self-mulching clay compared with sowing in bare soil. Long-term field observations are necessary to confirm this claim. Alternatively, mathematical models of expected establishment in mulched and in bare soils after various rainfall paterns might suffice. Data presented herein could aid in evaluating such a model.

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