Ameliorants to improve dry saline land patches in three-year demonstrations on upper Eyre Peninsula

Dr Buddhi Chaudhary[1,2], Amanda Cook[1,2,3], Craig Standley[1] and Kym Zeppel[1]

[1]SARDI; [2]The University of Adelaide; [3]Flinders University

Location
Minnipa, Penong, Karcultaby, Buckleboo

Rainfall
Karcultaby
2024 Total: 198 mm
2024 GSR: 162 mm
Buckleboo
2024 Total: 128 mm
2024 GSR: 91 mm
Penong
2024 Total: 171 mm (Ceduna)
2024 GSR: 85 mm
Minnipa
2024 Total: 191 mm
2024 GSR: 129 mm

Key messages

- **The application of ameliorants, such as sand, chaff and manure, can enhance plant establishment, growth and yield on dry saline land in some scenarios.**
- **Sand is the most effective ameliorant to improve crop growth and yield. High application rates (150-300 t/ha) and sand spread on top of the soil (80-100 mm) to reduce soil evaporation can help to improve growth on dry saline soils.**
- **Effective salinity management can be achieved through a combination of agronomic practices, including use of salt-tolerant varieties, seeding into soil moisture and management of the site to maintain groundcover.**

Why do the trials?

Salinity is a major issue in low rainfall regions, affecting crop and pasture and can be widespread due to water-table induced salinity or can be localised in patches within the paddock. Salinity in localised patches is traditionally referred to as “magnesia patches” and are often exacerbated by factors, such as sheep grazing and camping in this area, wind sweeping away sandy topsoil and lack of cover over the summer period, which increases soil water evaporation bringing salts to the surface. Poor plant growth and yield are commonly observed in affected areas due to reduction in the ability of crops to up take water from saline soil and the toxic effect of salt, particularly sodium (Na^+), in plants.

Salinity occurs due to the capillary rise of salt from subsoil profiles during the summer months. Although rainfall can wash salt particles to deeper into the soil profile, the process of capillary action and “wicking” draws salt back to topsoil under summer heat when the salt is within 1 m of the soil surface. This type of salinity is not associated with the saline water tables. The topsoil, particularly the top 5 cm, becomes toxic in low rainfall dry land (Telfer et al., 2023). Another form of salinity, known as transient salinity, occurs when salt particles are trapped between soil layers due to the low permeability of clay subsoils, with salt movement fluctuating depending on seasonal conditions.

Various innovative approaches have been tested and demonstrated to manage dry salinity across different regions. Some of the key management strategies includes selection of salt-tolerant crops and varieties, optimising sowing time following significant rainfall (Masters and Cook, 2022), and using soil cover with various amendments, including soil ameliorants.

In the Eyre Peninsula (EP) region, a landholder survey conducted by McDonough and Scholz (2021) found that the severity and production loss of saline soils has increased in recent years. The survey culminated in the further research and demonstration of various soil ameliorants in the EP regions in 2022. The South Australian Research and Development Institute (SARDI) conducted grower-level demonstrations at four sites in 2022: Buckleboo, Karcultaby, Minnipa Agricultural Centre (MAC N2) and Tumby Bay. Pre-sowing soil analysis (May 2022) of topsoils (0-10 cm) revealed contrasting salinity levels across sites; relatively low salinity at MAC and Karcultaby (<0.24 dS/m), but high salinity levels at Buckleboo (>1.0 dS/m). Different soil ameliorants were tested in various demonstration sites, sand was layered at Buckleboo, MAC and Karcultaby. Sheep manure/feedlot material was also spread on dry saline soil at MAC and Karcultaby. These trials showed improvements in crop establishment, biomass, and yield (Masters and Cook, 2022).

In 2023, demonstration trials continued at Buckleboo, MAC and Karcultaby, with two new sites established at Minnipa Hill and Penong, with improvement in crop establishments, biomass and yield (Telfer et al., 2023). In 2023, on upper Yorke Peninsula, trials evaluating management options found that applying a lower quantity of sand (0.16 - 0.62 t/ha) resulted in lower lentil yields compared to higher sand applications (1.3 t/ha). Additionally, a crop rotation of peas and canola after wheat produced higher yield than continuous wheat or wheat followed by barley (Trengove et al., 2023).

SARDI MAC continued monitoring some of the previously established demonstration sites in 2024, assessing crop establishment and yield. This report presents observations and results from 2024, while also consolidating three years of data from various demonstration sites. The findings will contribute to a better understanding of salinity management in the Upper EP and may inform the development of a "decision tree" tool for salinity management.

How was it done?

In 2024, MAC monitored four farmer-managed demonstration sites: Karcultaby, Buckleboo, Minnipa Hill, and Penong (Table 1). Of these, two sites (Buckleboo and Karcultaby) were started in 2022, while the other two (Minnipa Hill and Penong) commenced in 2023.

Karcultaby

At Karcultaby, sand (300 t/ha) and sheep manure feedlot material (8 t/ha) were spread using a tipper truck and trailer before sowing in May 2022. The sand and feedlot manure material was taken from the farms. In 2024, the measured depth of sand and manure material were 56 mm and 54 mm, respectively. A replicated trial was conducted, with plots measuring 2 m wide and 12 m in length. Data collection included amendment depth, plant density, the Normalised Difference in Vegetation Index (NDVI) and grain yield. The season was a decile 2 and sites received an annual rainfall of 198 mm, with a growing season (May – October) rainfall of well below average at 162 mm in 2024.

Buckleboo

At Buckleboo, sand was spread in strips using a land-plane scrapper with a low rate of sand (75 t/ha, approximately 75 mm depth) and high rate of sand (150 t/ha, approximately 150 mm depth) in 2022. It was an unreplicated trial with three control strips. The sand demonstration strips measured 15 m wide and 100 m in length and crossed over areas of better growth (low salinity) and areas of salt scald and poor growth. Observations and data collected included sand depth, plant density, NDVI and yield. The site received a decile 2 season with an annual rainfall of 128 mm, with a growing season (April - October) rainfall well below average at only 91 mm in 2024.

Penong

At Penong, drift sand was sourced from a nearby fence and applied in two rates: a high rate of 120 t/ha and a low rate of 60 t/ha in 2023 in a replicated trial with 15 m by 2 m plots. By 2024, the sand depth was measured at 80 mm in high rate and 50 mm in the low rate of sand. The site was sown using a SARDI zero-till plot seeder, with plot dimensions of 1.57 m in width and 15 m in length. Due to a poor season and late germination, plant counts were conducted on two separate dates: 5 July and 18 July 2024. Other measurements recorded were sand depth, NDVI and late-stage plant biomass. Severe drought conditions impacted the site limiting interpretation of yield data. The site received a decile 1 season with an annual rainfall of 171 mm at Ceduna, with a growing season rainfall of only 85 mm in 2024.

Minnipa Hill

At the Minnipa Hill site, crop chaff cart material (100 kg/ha) was spread on the saline patch within the paddock in December 2022 in preparation for the 2023 cropping season. The downhill lower flat area of the paddock had higher salinity than the hill area. The paddock had self-regenerating medic pasture in 2024, where NDVI and medic biomass were recorded as measurements. The sites received a decile 2 season with an annual rainfall of 171 mm with a growing season (April - October) rainfall of 129 mm in 2024.

Table 1. Summary of dry saline land demonstration sites in 2024.

Site Location	Demonstration type	Crop type and sowing date	Treatments (approximate rates)
Karcultaby	Soil ameliorants (Replicated)	2024 Calibre wheat 2023 Self regenerating medic pasture 2022 Barley (Scope CL)	Control - untreated Surface manure feedlot material @ 8 t/ha Surface sand @ 300 t/ha
Buckleboo	Soil ameliorants (Unreplicated due to different salinity zones, but multiple measurements within each treatment)	2024 Calibre wheat 2023 Sceptre wheat 2022 Oats (Yallara) and Vetch (Timok)	Control - untreated Low-rate sand @ 75 t/ha High-rate sand @ 150 t/ha
Penong	Soil ameliorants (Replicated)	2024 Calibre wheat 2023 Oats (Yallara) 2022 pasture	Control - untreated Low-rate sand @ 60 t/ha High-rate sand @ 120 t/ha
Minnipa Hill	Soil ameliorant (Unreplicated but multiple measurements within each treatment)	2024 Self regenerating medic pasture 2023 Barley	Control - untreated High chaff rate - 100 kg/ha

What happened?

Karcultaby

In 2024, the site was sown by the farmer with Calibre wheat @ 75 kg/ha on 15 May 2024. There was significantly higher plant density in the manure feedlot treatment (110 plants/m^2) compared to the nil (control) (Table 2). NDVI was higher in both ameliorant treatments (manure and sand) compared to the nil control (Table 2). The measured depths of ameliorant was 56 mm for sand and 54 mm for manure.

Grain yield was significantly higher in sand treatment compared to nil control, with more than double the yield of the nil control (Table 2). However, there was no significant yield difference between the manure and nil control treatments (Table 2).

The results are consistent with 2022 data, which also showed higher yields in the sand treatment compared to nil control. Additionally, winter biomass cuts and NDVI values were higher in the sand and manure treatments compared to the control (Masters and Cook, 2022). Dry matter production of self-regenerating medic pasture was 0.9-1.0 t/ha greater in the sand and manure compared to the nil control (Telfer et al., 2023).

Buckleboo

In 2024, the site was sown by the farmer with Calibre wheat @ 75 kg/ha on 13 May 2024. Results presented need to be interpreted with caution as only demonstration strips were established and there is no replication of results. In 2024, plant density was highest in high sand (126 plants/m^2), followed by the control (118 plants/m^2), and lowest in the low sand (110 plants/m^2) (Table 3). NDVI was lower in the control treatment compared to the sand-amended strips. Higher plant density combined with higher NDVI may have contributed to improve grain yield (combined bays yield), with the highest yield observed in the high sand (2.4 t/ha), followed by the low sand (1.8 t/ha) and the control (1.0 t/ha) (Table 3).

By 2024, sand depth measurements indicated 45 mm in the 150 t/ha high-rate treatment and 35 mm in the 75 t/ha low-rate treatment. The quantity of sand spread over the paddock and its depth coverage on the soil surface appears to provide agronomic benefits that contribute to increased grain yield. An analysis of sand depth and yield relationships showed a positive correlation, with grain yield increasing as sand depth increased (Figure 1).

Further analysis of yield across different bays showed Bay 2 (lower salinity) produced higher yield than the nil scalds-affected areas (Bay 1 and Bay 3). Additionally, the high sand strip consistently resulted in better yields compared to the low sand and no amendment control across most bays, although without replication of these demonstration strips this cannot be validated (Table 4).

A three-year review of overall performance in high and low sand treatments, compared to control, clearly demonstrated that sand amendments have had a positive impact on dry salinity management, leading to increased yield (Table 5). The higher sand application had a greater positive effect (Table 3 and Figure 2) compared to nil control where no sand was applied. However, due to the lack of replication in this demonstration trial these results should be considered with caution.

Table 2. Wheat performance in sand and manure soil amelioration at Karcultaby in 2024 on 2022 soil amendment treatments.

Treatment/rate (t/ha) (amendment depth in 2024)	Wheat establishment (plant/m²)	NDVI	Grain Yield (t/ha)
Nil Control	83 b	0.16 b	0.71 b
Manure (8 t/ha) (54 mm)	110 a	0.22 a	0.96 b
Sand (300 t/ha) (56 mm)	97 ab	0.25 a	1.61 a
LSD (F prob=-0.05)	*10.9*	*0.03*	*0.33*

Note: Different letter indicates the significance level at 5%.

Table 3. Average wheat performance in sand soil amelioration at Buckleboo in 2024 on 2022 soil amendments treatments. Note the results are not means and without replication should be interpreted with caution.

Treatment/rate (t/ha) (amendment depth in 2024)	Wheat establishment (plant/m²)	NDVI	Grain yield (t/ha)
High sand (150 t/ha) (45 mm)	126	0.5	2.4
Low sand (75 t/ha) (35 mm)	110	0.5	1.8
Control (no added sand)	118	0.3	1.0

Soils

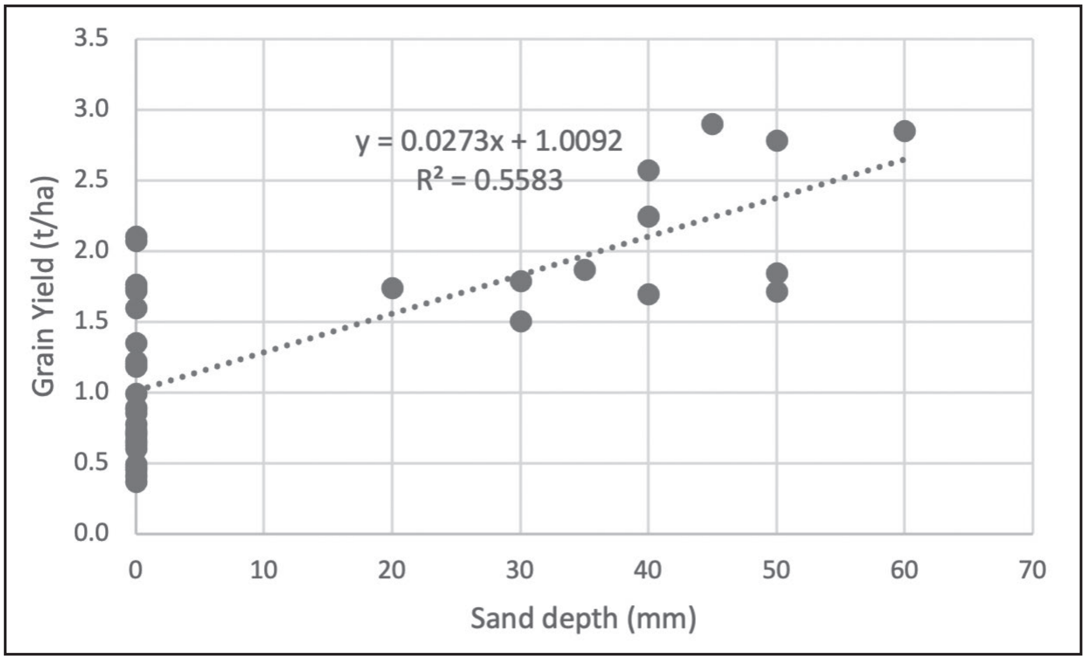

Figure 1. Relationships between depth of sand ameliorant spread in 2022 to wheat grain yield at Buckleboo in 2024.

Table 4. Calibre wheat grain yield (t/ha) under sand amendments to manage salinity at Buckleboo in 2024. Note the results are not means and without replication should be interpreted with caution.

Treatment - sand rate t/ha (amendment depth in 2024)	BAY 1 Western Scald	BAY 2 Lower Salinity	BAY 3 Eastern Scald
Control 0 (better production area)	0.9	1.3	0.5
Low sand - 75 t/ha (35 mm)	2.0	1.8	1.7
Control 1	0.7	1.7	0.7
High sand- 150 t/ha (45 mm)	2.7	2.9	1.8
Control 2	0.5	2.0	0.7

Table 5. Three-year yield performance (2022 - 2024) of different crops in sand amended saline soil at Buckleboo. Note the results indicating improvement are from trials without replication and should be interpreted with caution.

Treatment - sand rate t/ha	2022 - Vetch and Oat	2023 - Calibre wheat	2024 - Calibre wheat
High sand (150 t/ha)	Improved biomass	Improved yield	Improved yield
Low sand (75 t/ha)	Medium biomass	Medium yield	Medium yield
Control (no added sand)	Lowest biomass	Lowest yield	Lowest yield

Source: EPFS Summary 2022, 2023 & 2024.

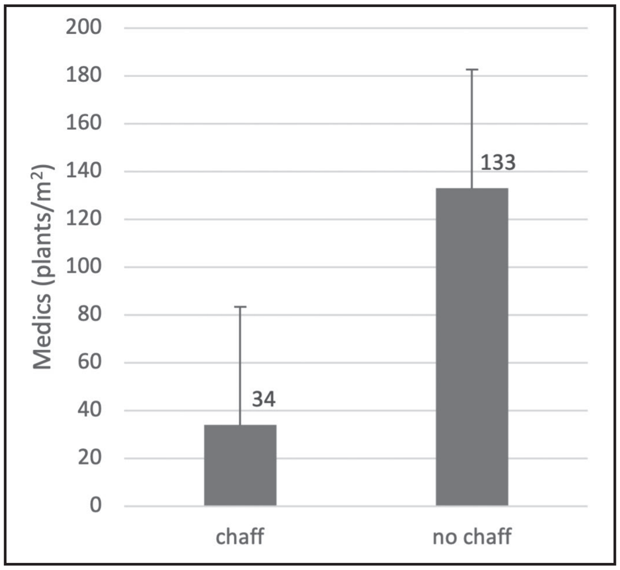

Figure 2. Medic density (plants/m²) under chaff and no chaff at Minnipa Hill 2024.

Penong

In 2024, the site was sown by SARDI MAC with Calibre wheat @ 75 kg/ha on 5 June 2024. Due to staggered emergence, plants counts were conducted on two different dates: 5 July and 18 July 2024. There was no significant difference in plant density, NDVI, early biomass and grain yield between the different sand amendment levels. The average sand depth was 80 mm in the high level of sand and 50 mm in the low sand treatment with the sand spread in 2023.

The sites received low rainfall (85 mm) during the crop growing season (May – October). Rainfall was very low in September (5 mm) and October (10 mm), leading to severe drought conditions during the reproductive stage of the crop. Crop biomass was measured as an indicator of potential yield. There was no significant difference in plant density, NDVI, early plant DM and grain yield of treatments. The mean grain yield was 0.2 t/ha that was more than half lower yield (<0.5 t/ha) than the farmer.

In 2023, there were biomass and yield benefits in the sand, but these were not significantly different from the nil control.

Minnipa Hill

The paddock had self-regenerating medic pasture in 2024. Crop chaff (100 kg/ha) was spread during harvest in December 2022 in preparation for the 2023 growing season. The paddock has low salinity at the hill area and high salinity down in the lower flat area. The chaff layer measured 65 mm across both the hill and low flat.

The chaff effectively covered the soil surface, reducing the medic establishment in the self-regenerating pasture. The medic population was much lower in the chaff area (34 plants/m²) compared to the non-chaff area (133 plants/m²) (Figure 2). However, the medics in the chaff appeared to be more vigorous in growth than those in the no chaff treatment. NDVI in the chaff was 0.2 and was 0.3 in non-chaff area. There was no difference in NDVI between the hill and lower flat areas of the paddock.

Dry matter production of medic pasture (t/ha) was high in the non-chaff areas (5.2 t/ha at the hill and 3.3 t/ha in the lower flat) compared to the chaffed areas (2.8 t/ha at the hill and 3.1 t/ha in lower flat) (Figure 3). This is supported by the higher medic population and higher NDVI which contributed to improved dry matter in the no chaff saline soil patch of the paddock. This finding is supported by data from 2023, where higher barley yield was reported on the hill and chaffed areas (Telfer et al., 2023). The better yield in the chaffed areas provides evidence that the chaff reduced salinity and minimised weed pressure, including medics.

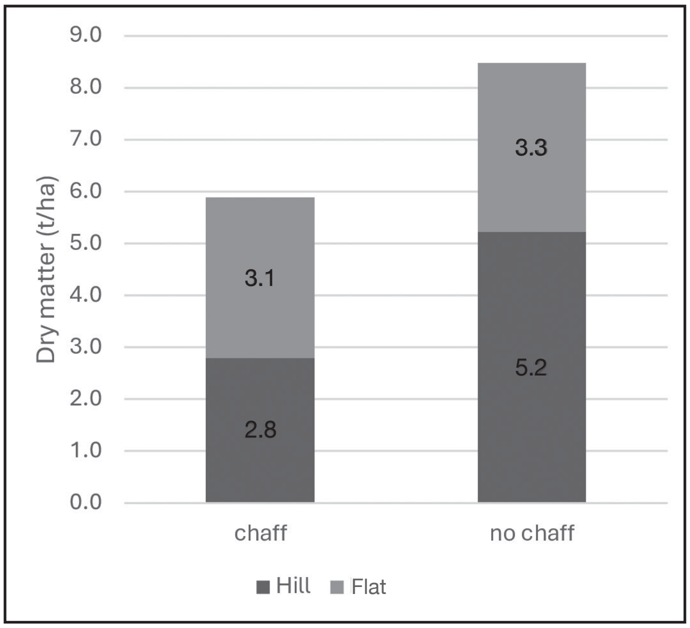

Figure 3. Medic pasture dry matter (t/ha) under chaff in varied landscape conditions at Minnipa Hill, 2024.

Soils

What does this mean?

The three-year demonstration results at seven sites in the upper Eyre Peninsula region, has enhanced the knowledge base on the application of soil ameliorants to manage dry salinity. The results are consistent across most sites in the region, except for Penong (located in the far west of the EP), which was affected by drought conditions in both 2023 and 2024.

Soil amelioration is effective in improving plant establishment, growth and grain yield in some scenarios. The level of impact varies depending on the type, quantity and quality of amendment materials used on the saline patches. Farmers demonstrated crop chaff, sheep manure from the feedlot and sand in various quantities across the EP regions. Sand was found to be the most effective in managing dry salinity in most demonstration sites, such as Buckleboo, Minnipa (MAC N2) and Karcultaby. Sand application also improved medic pasture dry matter at Karcultaby. In contrast, crop chaff reduced the number of self-regenerating medics, but improved grain yield as seen at Minnipa Hill. Chaff acts as a mulch, covering the soil surface, reduces evaporative capillary rise of salt and limits weed germination. Feedlot manures demonstrated moderate effectiveness in salinity management (MAC N2 and Karcultaby) compared to sand. Using feedlot material and spreading into broadacre paddock may also increase the risk of spreading weeds, so knowledge of potential weed issues and monitoring the area is important. However, the manure may offer the added benefits of improving soil physical, chemical and biological properties over the long term, which have not been assessed in this study.

The quantity of amendment materials was also demonstrated in various locations (Table 1). Sand amendments were demonstrated at Buckleboo (75 t/ha and 150 t/ha), Penong (60 t/ha and 120 t/ha), Minnipa MAC N2 (300 t/ha) and Karcultaby (300 t/ha). At most sites the higher rate of sand produced better yields. The benefits of high application of sand in lentil yield is also reported in Tickera, Yorke Peninsula (Trengove et al., 2023). It is reported that sand above 650 t/ha can improve wheat grain yields, and high sand application (1300 t/ha) was the only treatment that improved lentil yield (Trengove et al., 2023). Soil tests indicate that 8 cm application of sand can reduce salinity for several years and remain effective for up to 10 years (Telfer et al., 2023).

Using sand as an ameliorant will depend on the availability of quality sand, its application and the associated costs. It is particularly important to test and ensure that the sand applied is salt-free. For example, moderate salinity was found in an ameliorated sand at Minnipa which resulted in lower benefits (Master and Cook, 2022). Similarly, the application of sand and manure on heavy clay soils had negative effect (Telfer et al., 2023). This highlights the need for caution when ameliorating clay soil. Application of technology, the logistics of moving the sand and associated costs are other factors that farmers must consider, alongside achievable yield.

Targeted application of amendment materials in saline patches may enhance efficiency in salinity management. The use of satellite mapping and EM38, can assist in identifying saline patches and determining the require amounts of amendment materials (Telfer et al., 2023). However, there are also risks associated with the spread of weed seeds in new area or paddock through the amendments (feedlot manures, chaff and sand).

Agronomic management options play a crucial role in salinity management. Selecting the right crops and varieties is one of the most economical strategies. Barley and oats are reportedly more tolerant to salinity than wheat (Telfer et al., 2023). Crop rotation with a tolerant break crops was found to yield better in saline soil, with canola and pea rotation after wheat yielding higher than a wheat then barley rotation in Tickera, upper Yorke Peninsula (Trengove et al., 2023). Farmers have also noted that sowing after a substantial rainfall event improves crop germination, growth and yield in low rainfall regions rather than sowing dry or on marginal moisture (Telfer et al., 2023).

Salinity management strategies vary depending on soil types, paddock topography and climatic conditions. An appropriate management strategy can help growers manage saline soils more effectively. The Future Drought Fund project has developed a web-based interactive Decision Tree for Dry Saline Land that allows farmers to assess their situations and follow the key principles to improve their soils.

Conclusion

Based on three-year of research and demonstration across multiples sites in the Eyre Peninsula region using various soil amendments materials, it can be broadly concluded that amelioration improves crop emergence, growth, and yield. Amendments with sand yielded better results and higher quantities of sand (>150 t/ha) covering thick soil top layer (8-10 cm) acts as a soil cover for many years. Farm feedlot manures and chaffs are also effective in covering soil and improving crop yield in some scenarios. Chaff could be the convenient alternative of sand, as it can be spread during the crop harvest. There is a need for identification of saline patches, estimation of the required quantity of ameliorants, the associated cost and the appropriate machinery for application.

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