WINCHMORE: THE WORLDS OLDEST GRAZED AND IRRIGATED PASTURE TRIALS

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Abstract
The Winchmore field trials, located in the Canterbury Plains, hold the distinction of being the world's longest-running trials of grazed pasture under irrigation. The trials were designed to measure i) the response of pasture (ryegrass/white clover) production and productivity to increasing rates of phosphorus (P) fertiliser (Fertiliser Trial), and ii) the response of pasture that received the same rate of P fertiliser but different rates of irrigation (Irrigation Trial). The Fertiliser Trial consists of 20 plots (0.09 ha), divided into five treatments each with four replicates. Treatments applied annually since 1952 include 0, 188 and 375 kg ha^{-1} of single superphosphate (SSP). Between 1952–1958, the two other treatments received annual applications of 376 and 564 kg SSP ha^{-1}, which then ceased. In 1980, annual fertiliser application resumed on these treatments, one receiving 250 kg SSP ha^{-1}, the other reactive phosphate rock/sulphur at 22 kg P ha^{-1} (equivalent to 250 kg SSP ha^{-1}). The Irrigation Trial consists of 24 plots, divided into five treatments each with four or five replicates. Between 1958–2007, all plots received 250 kg SSP ha^{-1} annually, with different rates of irrigation. These included an unirrigated treatment, irrigation applied when moisture (top 100 mm of soil) reached 10, 15, 20%, and irrigation applied on a 21-day interval. Nearly 7000 soil samples collected from the trials have been archived. About 96,000 records have been complied of soil chemical and physical data, pasture yield and botanical composition. These data have been used in 475+ publications that have explored topics including improvements in livestock production, the efficacy and scheduling of irrigation, improvements in pasture production, agronomic and environmental soil and water research, and entomology. Further, data from the trials has been invaluable for calibrating models developed to predict issues such as carbon accumulation in soils. The aims of this paper are to introduce or remind folk of the Winchmore trials, to highlight some of the findings over the last 70 years and invite interested researchers to utilise the Fertiliser Trial site, archived samples and datasets to undertake new scientific investigations that benefit New Zealand's environment and agricultural sector.

Introduction

The Winchmore Irrigation Research Station, located in the Canterbury Plains (43.787° S, 171.795° E), is home to the world's longest-running trials of grazed pasture under irrigation. The trials, which commenced over 70 years ago, were designed to measure i) the response of pasture (ryegrass/white clover) production and productivity to increasing rates of phosphorus (P) fertiliser (Fertiliser Trial) and, ii) the response of pasture that received the same rate of P fertiliser but different rates of irrigation (Irrigation Trial).

The trials' initial focus on production and productivity has generated numerous valuable insights on managing grazed pastoral systems receiving P fertiliser and irrigation in New Zealand. However, the trials have also provided the opportunity to gain a better understanding of a diverse range of other issues facing the agricultural sector in New Zealand not considered at the outset of the trial. These include nutrient accumulation and cycling in soils and environmental issues around water and soil

quality. The trials have provided data to support several hundred scientific publications as well as being used in the calibration of farm management models. The setup and management of the Winchmore trial and some of the key findings from research undertaken at the site has been highlighted in a special edition of the New Zealand Journal of Agricultural Research in 2012 (Smith et al. 2012). It also includes a comprehensive bibliography of studies published from the trial (Cousins and McDowell 2012).

In addition to the large body of published work, Winchmore also maintains an archive of soil and fertiliser samples from the trials. Further, records have been compiled of soil chemical and physical data, pasture yield and botanical composition collected from the trial, along with information related to the trial design and metadata. A summary of the archived soils/fertilisers available and the data collected from the trials has been reported in a data descriptor paper in Nature Scientific Reports (McDowell et al. 2021).

The aim of this paper is twofold. Firstly, introduce and/or remind researchers, advisors and regulators of the Winchmore trials, running for over 70 years. Secondly, extend an invitation to interested researchers to use the ongoing Fertiliser Trial site (the Irrigation Trial has been discontinued), as well as the archived soil samples and datasets from both trials that are available to undertake new investigations that may be of benefit to New Zealand's environment and agricultural sector.

Trial set up and treatments

The Winchmore Irrigation Research Station located in the Canterbury Plains is at an altitude of 160 m above sea level, has a mean annual temperature of 12 °C, and annual rainfall of 745 mm (range 491–949 mm) (Rickard and Moss 2012). The soil is a Lismore stony silt loam classified as an Orthic Brown soil (Hewitt 2010). Full details of the two long-term field trials established at the research station, hereafter known as the Fertiliser and Irrigation trials have been reported in Rickard and Moss (2012) and McDowell et al. (2021).

In brief, the Fertiliser Trial consists of 20 plots (0.09 ha), divided into five treatments each with four replicates. Treatments applied annually since 1952 include 0, 188 and 375 kg ha^{-1} of SSP. Between 1952–1958, two other treatments received annual applications of 376 and 564 kg SSP ha^{-1}, which then ceased. In 1980, annual fertiliser application resumed on these treatments, one receiving 250 kg SSP ha^{-1}, the other reactive phosphate rock (RPR)/sulphur (S) at 22 kg P ha^{-1} (equivalent to 250 kg SSP ha^{-1}). Each treatment plot was fenced off and grazed by separate mobs of sheep at 6, 11, and 17 stock per replicate for the nil, 188 SSP, and 376 SSP treatments, respectively. No grazing occurred in winter. Border-check/dyke irrigation was applied when the soil moisture content (w w^{-1}) fell below 15% (0–100 mm depth), on-average 4.3 times per year. However, irrigation from 2018 onwards changed, and is now applied by variable rate spray irrigation, with the aim of ensuring soil moisture is maintained at 90% of field capacity. Since January 2019 there are daily soil moisture meter records from a moisture meter installed into one of the fertilised plots. Soil moisture, rainfall and irrigation data are recorded.

The Irrigation Trial consisted of 24 plots, divided into five treatments each with four or five replicates. Between 1951 to 1956/57 there were a mix of different irrigation rates that are detailed in Rickard and Moss (2012). In 1958, the site was cultivated, 140 kg SSP ha^{-1} applied and re-sown in a ryegrass/ white clover mix. From 1958–2007, all plots received 250 kg SSP ha^{-1} annually, with different rates of irrigation. These included an unirrigated treatment, irrigation applied when moisture (top 100 mm of soil) reached 10, 15, 20%, and irrigation applied on a 21-day interval. Irrigation was applied at a rate of 100 mm per event. Except for winter, when no grazing occurred, each treatment was rotationally grazed by a separate flock of sheep with 6 and 18 stock units per replicate for the unirrigated and 20% v/v treatments, respectively. The irrigation trial finished in October 2007.

Sampling and analysis

Pasture

Pasture production has been measured using the rate of growth technique using two movable pasture exclusion cages (3.25 m long × 1.02 m wide) per plot (Radcliffe 1974; Lynch 1960). Areas within each cage were trimmed to 25 mm above ground level and left for a standard grazing interval for that time of year. Following each grazing interval, a lawnmower was used to harvest a 0.40 m wide strip in the middle of each enclosure to 25 mm above ground level, with all plots harvested simultaneously. The wet weight of pasture was measured, and a sub-sample taken to determine dry matter percentage. Approximately 9–10 cuts were made annually. A separate sample was manually dissected into grass species, white clover and weeds to determine botanical composition of the pasture four times over the growing season (September, November, February, May) using the method described in Lynch (1966).

Soil

Annual sampling involved collecting a composite soil sample of 12 cores (2.5 cm diameter and 7.5 cm deep) from each plot four times, in August, prior to fertiliser application, and in November, February, and May. Cores were taken at random following a diagonal route end to end from each plot. The surface pasture/thatch was removed from samples that were air-dried and sieved to 2 mm for storage and later chemical analysis.

In addition to annual sampling, there have been some ad hoc soil samples collected from the site. In 2009 soil samples were collected from the 0–75, 75–150, 150–250, 250–500, 500–750, and 750–1000 mm depths on both trials (Condron et al. 2012). Samples were crushed, dried and sieved <6 mm and retained for chemical analysis. During 2017, soil on all treatments of the fertiliser trial were sampled using a soil corer to 0–75, 75–150, 150–300, and 300-500 mm depths at five equally spaced distances centrally located down each plot. A further series of soil samples was obtained from the fertiliser trial during 2018 from the nil, 188 and 376 kg SSP ha^{-1} yr^{-1} treatments at 0–75 and 75–175 mm depths at five equally spaced distances down and five locations across the plots. During 2018, soil on the unirrigated, 10 and 20% soil moisture treatments of the irrigation trial were sampled at 0–150, 150–250, 250–500, 500–750, 750–1000, 1000–1500, and 1500–2000 mm depths. The top 250 mm of these samplings were collected by hand using an auger, but deeper depths were excavated via a mechanical digger. Representative sub-samples were taken from each depth.

Routine analysis of soil samples included Truog P (1952–1981), Olsen P concentration (1976–onwards), pH in water, exchangeable cations (potassium (K), magnesium (Mg), calcium (Ca) and sulphate-S. Intermittently, there has also analysis for organic S, reserve K, inorganic P, organic C, organic matter and total C, total cadmium (Cd), fluorine (F), and uranium (U). Stored samples of the fertilisers applied between 1998–2010 have also been analysed for total nutrient and heavy metal concentrations.

Outputs

Data from the Winchmore trials have been used in a wide range of academic areas and subsequent extension efforts with farmers. These data have been used in 475+ publications that have explored topics including improvements in livestock production, the efficacy and scheduling of irrigation, improvements in pasture production, agronomic and environmental soil and water research (Cd, F, P loss), and soil biology (earthworms, insects, microbes). It has also been used in the calibration of models developed to predict issues such e.g. C and Cd accumulation in soil. A summary of much of this research from the Winchmore trials has been highlighted in a special edition of the New Zealand Journal of Agricultural Research in 2012 (McDowell and Smith 2012), and more recently in a data descriptor paper in Nature Scientific Reports (McDowell et al. 2021).

Access to the fertiliser trial site, dataset and soil archived soils samples

In 2018, with the sale of the research station, but retaining a long-term lease of the fertiliser trial site, the Winchmore Management Forum was set up to manage the Winchmore Long-Term phosphorus trial. It comprises members from the Fertiliser Association of New Zealand (FANZ) and AgResearch. One of the aims of the Winchmore forum is to invite interested researchers to utilise the Fertiliser Trial site, archived samples and datasets to undertake new scientific investigations that benefit Aotearoa New Zealand's environment and agricultural sector.

Access to the fertiliser trial site

The Fertiliser trial site is available to be used by researchers to undertake new scientific investigations. This may include obtaining new soil and pasture samples or applying treatments to the trial site on the proviso that that any treatment will not negatively impact the ongoing viability of the trial. Obtaining access to the site involves contacting the Winchmore Management Forum at winchmore@agresearch.co.nz and providing detail of the proposed research. The forum will assess the merits of the application to determine whether it's of national interest, is being undertaken by a reputable research organisation, supports significant issues for NZ agricultural industries, without compromising integrity of the long-term trial and that any soil collected or data gained will be available to be archived/stored.

Access to data

About 96,000 records of soil chemical and physical data, pasture yield and botanical composition from the two trials are available in five spreadsheets (https://doi.org/10.6084/m9.figshare.13530209 (McDowell 2021). The data includes i) soil chemistry data (pH, SO_4, Olsen P, exchange Ca, Mg, Na, K), ii) soil contaminants (Cd, F, U) iii) annual pasture DM production iv), monthly pasture growth, v) quarterly pasture composition (grass, clover, weed) and vi) some fertiliser data (major and trace nutrients, contaminants). The data is available on request by emailing the Winchmore Management Forum at winchmore@agresearch.co.nz, although the data remains the property of the funders (e.g. the New Zealand Government, AgResearch Ltd, and the Fertiliser Association of New Zealand). Access to the data is contingent on the user completing a Data Use Form, indicating the reason for the request so the forum can assess the merits of the application. Data files will be supplied in a read-only format to avoid the chance of the data being unintentionally comprised.

Access to soil samples

Nearly 7000 dried, sieved (<2 mm) soil samples have been collected from the trials and archived, as well as some of the fertiliser samples that were applied to the trial. Soil and fertiliser samples are available on request by emailing the Winchmore Management Forum at winchmore@agresearch.co.nz. Access to the samples is contingent on the user completing a Data Use Form, indicating the reason for the request so the forum can assess the merits of the application. This is important given the small and finite volume of soil available. Samples would only be provided on the understanding that any data gained will be available to be archived in this database.

Summary

The Winchmore Field Trials have allowed us to monitor and document the effects of consistent and uniform use of phosphate fertiliser and irrigation management over 70 years. It has also provided data that have been used by researchers to investigate a range of agronomic and environmental issues not envisaged when the trial was initiated. The future of the long-term fertiliser trial has been secured with a lease in place to the FANZ out to 2052. The site is managed by AgResearch on behalf of the FANZ. The Winchmore Management Forum hopes this paper will provide a catalyst for scientists, researchers, and farmer groups to utilise the Fertiliser Trial site, archived samples and datasets to

undertake new scientific investigations that benefit Aotearoa New Zealand's environment and agricultural sector.

References

Condron LM, Black A, Wakelin SA 2012. Effects of long-term fertiliser inputs on the quantities of organic carbon in a soil profile under irrigated grazed pasture. New Zealand Journal of Agricultural Research 55: 161–164.

Cousins KA, McDowell RW 2012. Bibliography of research from the Winchmore Irrigation Research Station, Canterbury, New Zealand: 1951 to 2011. New Zealand Journal of Agricultural Research 55: 181–206.

Hewitt AE 2010. New Zealand soil classification - 3rd edition, Manaaki Whenua Press, Landcare Research, Lincoln.

Lynch PB 1960. Conduct of field experiments. New Zealand Department of Agriculture Bulletin 399. 72pp.

Lynch PB 1966. Conduct of field experiments. 155 (New Zealand Department of Agriculture, Wellington, New Zealand, 1966).

McDowell RW, Smith C 2012. The long-term Winchmore trials: 60 years of discovery. New Zealand Journal of Agricultural Research https://www.tandfonline.com/toc/tnza20/55/2

McDowell RW 2021. The Winchmore long-term Fertiliser and Irrigation Trial data. Figshare https://doi.org/10.6084/m9.figshare.13530209.

McDowell RW, Moss R, Gray CW, Smith LC, Sneath G 2021. Seventy years of data from the world's longest grazed and irrigated pasture trials. Scientific Reports 8:53 https://doi.org/10.1038/s41597-021-00841-x.

Rickard DS, Moss RA 2012. Winchmore and the long-term trials: the early history. New Zealand Journal of Agricultural Research 55: 93–103.