

Final Report

On Farm Quality Testing Utilising Near Infrared (NIR) Technology

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MG17002

Project:

On Farm Quality Testing Utilising Near Infrared (NIR) Technology – MG17002

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Summary

Harvesting at the correct maturity level, as measured by dry matter (DM), is critical to the development of flavour, as measured by Brix, in mangoes (Walsh *et al* 2007). On farm quality testing utilising near infrared (NIR) technology to determine the percentage of dry matter (%DM) in mango fruit has been used as a measure of harvest maturity alongside other maturity indicators such as fruit size and shape, internal flesh colour, skin texture as well as flowering times and heat sum calculations. The Australian mango industry has used this technology of non-destructive on farm dry matter testing to assist Australian mango growers in the 'decision to pick' process over the past three seasons. As the DM testing is non-destructive it allows many fruits to be sampled quickly in field before harvest, in the packing shed or in the market. It also allows for repeat sampling of designated blocks over the fruit development period which allows growers to analyse trends over time to effectively plan their harvest.

This project set out to achieve continued industry adoption of the NIR technology. Preseason roadshow presentations provided the platform to continue to engage with all of industry to ensure that quality remains a key driver for growers to ensure improved profitability. This project is an extension of the Hort Innovation MG16002 Fruit maturity assessment on farm using NIR and addressed the opportunity to educate more stakeholders including growers as well as continued support for growers in the lead up to harvest and their decision to harvest. Growers could self-nominate for assessment when the Australian mango team members along with the machines were available in their area and in some regions the machines were in the care of a nominated person to allow access for individual when required.

This project was to provide for on farm quality testing for growers using hand held NIR technology for the period from August 2017 to December 2017 to ensure that growers are fully aware of industry minimum quality standards and ensure that growers have access to tools and procedures to assess maturity to ensure that mangoes are harvested at optimal maturity to align with consumer eating preferences. The project successfully demonstrated the use of the NIR F750 machine across 9 regions, visiting 90 mango orchards throughout Western Australia, Northern Territory, Queensland and Northern New South Wales. The project recorded data on over 8,000 scans, on 5 varieties (Calypso, Honey Gold, Kensington Pride, Kielt and R2E2) of mangoes. This season saw approximately 30 new growers reached through this project than the previous project.

There were areas of improvement identified throughout this project. These included the addition of calibration stickers to clearly identify the last calibration date of the machine as well as home screen improvements. Outcomes of the investigation into a spectrometer hardware malfunction during a routine DM testing (the first recorded malfunction of its kind in Australia to date) sees continual improvements to the technology to include display screen hardware error messages for instant detection. On the wider scale of consideration, the technology is currently being trialled within other produce lines in the fresh produce industry such as avocados. The research to develop a minimum dry matter standard for Keitt and confirm the R2E2 Dry Matter standard is at the right level has been deferred to another project due to funding.

Overall the project found that the NIR produce quality meter technology was a useful tool being embraced by more Australian mango growers and industry stakeholders including exporters, retailers and wholesale markets.

Keywords

Decision to pick; dry matter testing; Felix 750 Quality Produce machine; flavour; mango maturity standards; near-infrared; non-invasive; quality.

Introduction

On farm quality testing utilising near infrared (NIR) technology has been a cornerstone of the industry's focus of improving the eating quality of mangoes by introducing new minimum dry matter standards for mangoes at harvest. Previous research investigating alignment of mango quality standards with key industry practices and knowledge of consumer expectations identified that the most likely issue with the industry's quality standards and consumer expectations was with respect to fruit maturity.

In the past three seasons, the on farm dry matter testing that assists growers in the 'decision to pick' process has formed a critical component of previous projects listed below:

- MG14504 Mango Quality standards, led by Terry Campbell, Queensland Department of Agriculture and Fisheries (QDAF).
- MG15002 Quality standards, refinement and testing, led by Noel Ainsworth (QDAF).
- MG16002 Fruit maturity assessment on farm using NIR, led by Greg Owens, Northern Territory Farmers Association (NTFA).

Each of these projects focused on aspects of quality, with MG14504 also undertaking consumer research to assess the most appropriate minimum dry matter standards for two varieties (Kensington Pride and R2E2). Both MG14504 and MG15002 also delivered training on quality for major retailer staff in major capital cities. MG16002 principal focus was the delivery of on farm dry matter testing with the aim of assisting growers with the decision to pick in key regions throughout Australia. This project was completed on 30th April 2017. MG17002 commenced on the 1 September 2017.

The maturity of the first ripe eating mangoes of the season sets the tone of the market for much of the season. If that fruit is mature and ripens well to good eating quality and appearance, then the market price and volume flows will remain higher and with better returns for growers. It is critical for the mango industry that the early fruit, especially the main variety Kensington Pride (KP), is harvested at the required maturity and the consumer has confidence in the flavour of the mango they have purchased. This will lead to repeat purchases, consistent throughput and maintain higher returns for the season. If mangoes are harvested before they have reached the correct maturity they will not reach their flavour potential.

The current mango strategic investment plan 2017-2021 page 9 states;

"The mango industry has increased its focus on quality such that it is a key component underpinning its marketing strategy, commonly known as the Wheel of Velocity and Momentum. Quality standards have been established, including dry matter content measured using non-invasive technologies, such as near infrared (NIR) technology calibrated to each variety. While there have been some challenges with NIR calibrations for mango quality, increasingly quality parameters are being measured on-farm and throughout the supply chain and are being reported weekly during the season".

Mangoes have a limited window of readiness and timing the harvest window for each block/orchard is critical for ensuring optimal eating quality and commercial viability. Traditionally grower's decision to pick was based on a number of measures, including heat sums, fruit shape, flesh colour and dry matter. Dry matter sampling using a destructive sampling process has been the industry's standard methodology. This technique relied upon selecting a small number of fruit picked at various stages of maturity and could take over 48hours to produce results. More recently the development of NIR has enabled growers to assess fruit maturity using a rapid, non-destructive method. The critical control points for assessing maturity are at time of picking and at retail Distribution Centres. While this improves grower's ability to make the decision to pick, the NIR tool needs to be calibrated for each variety and more data needs to be generated to ensure the NIR calibration is robust and able to be used under a range of conditions. This project was designed to enable growers to have mango maturity checked prior to commencement of harvest. The project funded staff from AMIA with the support of local industry groups and growers who owned their own machines to assist growers with the decision to pick process using NIR technology with the Felix 750 Produce Quality Meters.

This project was the continuation of enabling growers to check mango maturity prior to the commencement of harvest.

Methodology

This project funded the application of NIR technology into the decision to pick process for growers throughout Australia. Utilising two Felix 750 Produce Quality meters, staff members from AMIA (Samantha Frolov and Jessica Mitchell) visited growers in the lead up to harvest and provide advice on DM levels of fruit in blocks/orchards prior to harvest to aid them with their decision to pick process by providing NIR testing.

Felix 750 Produce Quality meters, calibration and validation

The process utilised two industry funded Felix 750 Produce Quality meters to assist with the decision to pick process and was aided by supporting departments machines and privately-owned machines when required by local growers. In the early part of the season, both industry meters were used in the Northern Territory (September, October, November). Prior to the start of the Queensland season, one meter was used in Queensland, Bowen/ Burdekin (late October/November) and then used in Mareeba/Dimbulah (November, December and January for late season varieties) followed by central and south east Queensland (December/January/February) as well as northern New South Wales. In the later part of the season the newly purchased and calibrated Western Australia Department of Primary Industries and Regional Development (WADPIRD) machine was utilised in the Gingin region of Western Australia (February). Due to timing in shipment from USA, this machine was not available for the Carnarvon and Kununurra regions. Staff members from Northern Territory Department of Primary Industries and Resources (NTDPIR) and WADPIRD assisted AMIA by visiting growers in Kununurra to aid them with their decision to pick process by providing NIR testing (December).

In preparation for the season, the Felix 750 Produce Quality meters need to be calibrated for each of the key varieties. The initial calibration process was undertaken with 20 pieces of each variety of fruit, measuring dry matter on both cheeks of the sample of fruit and then calibrating the meter against the dry matter measured in the traditional method (measuring and weighing a sample of mango flesh from each mango and then drying and weighing to measure dry matter content). Each meter underwent a validation calibration during the season to ensure accuracy of measurements. These calibrations were undertaken, the process lead or supported by staff from Central Queensland University in the relevant region.

On farm visits

As there are different amounts of growers with different varieties in each region, it is difficult to quantify an exact number per variety, per region. AMIA initially targeted all growers that are on our forecasting database (approximately 70), as these growers represent approximately 90% of production to schedule at least one visit with. When these visits were conducted, growers were asked if they would like a subsequent visit dependent on when the AMIA team was available and when the grower was harvesting. Every effort was made to conduct a visit where possible. These growers grow all the major varieties that the machines are calibrated for (Kensington Pride, R2E2, Honey Gold, Calypso and Keitt). Outside of growers on the forecasting database, the next target group of growers were those with an unfavourable objective report. (i.e. below the dry matter industry quality standard). It was important to show these growers on-farm, what level their dry matter is at (on average), so that hopefully their next consignment that is sampled as part of objective reporting, is above the dry matter industry quality standard. Finally, all growers that subscribe to AMIA communication, receive a notification via AMIA communication materials, ahead of Jessica and Samantha visiting each region. Any grower could contact AMIA to receive a visit and access this service. Every effort will be made to conduct a visit where possible.

Dry matter recordings

%DM data was recorded in accordance with the individual grower's requirements. This was usually done on a variety and block basis with a summary of the data returned to the grower showing the average %DM, maximum and minimum values and a standard deviation for the block. Individual fruit data was available to the grower if requested. This summary data was recorded in a spreadsheet of results (Appendix 1) and then summarised across the regions.

Consumer Research

Consumer Research on a dry matter industry quality standard for Keitt, and to re-test the minimum dry matter industry quality standard for R2E2, was to be conducted in-line with previous consumer research conducted to develop the 2016 dry matter industry quality standards for R2E2, Kensington Pride, Honey Gold and Calypso. Due to budget constraints this component of the project was removed from this project with the intention it be included in the next project.

Outputs

In August 2017, the Felix F 750 Produce Quality meters were calibrated in Darwin by the UCQ team and included training of staff from Rudge Produce Systems. The machines which included a mix of privately owned, state departments and industry machines were calibrated for Calypso, Honey Gold, Kensington Pride and R2E2 varieties. The calibration was conducted on varying maturities of mangoes. Calibration (validations) were also conducted throughout the season and included fruit from across the different regions including NT, Qld (Appendix Three, Ref. E) and WA. An example of the calibration summary is attached. (Appendix One)

Regional visits commenced earlier than the previous season. Grower/orchard/packhouse visits were booked with growers prior to visiting the region and were advertised in the weekly communications *My Mango*.

Samantha Visiting SEQ Region With Felix Meter

This week and next week, Samantha will be visiting growers around the Bundaberg, Gladstone and Rockhampton areas, with the Felix F-750 Produce Quality Meter.

If you would like to know more or to arrange a visit, please contact Samantha on (07) 3278 3755 or 0400 810 365.

AMIA engaged with growers on farm and provided on farm quality testing using hand held NIR technology during the lead up to each regions commencement of harvest and continued the on-farm quality testing for the period from 1 August 2017 to 31 March 2018. AMIA personnel ensured that growers had the opportunity to become fully aware of industry minimum quality standards and ensured growers had access to tools and procedures to assess maturity so that that mangoes were harvested at optimal maturity to align with consumer eating preferences. This included a verbal update of the standards and either a handout of the printed version of the 2016 Mango Industry Quality Standards or an emailed copy of the link for reference whilst packing during the season. Link provided below;

<https://static1.squarespace.com/static/53b0ef57e4b04ed3deabc4f/t/57ec91af2e69cf2c061af585/1475121584250/2016+Mango+Industry+Quality+Standards.pdf>

AMIA encouraged growers in regions to become familiar with the tool and the process. This was achieved by inviting growers to test their own fruit with the machine in field with support from AMIA staff. This season AMIA wished to further instil confidence in the growers by leaving a machine in one region to further encourage growers to take the machine 'home' and use the it themselves in field. The personnel in charge of the machines were trained in how to use the machine as well as how to download and interpret data captured through testing in field.

Felix Meter Available for use in Mareeba / Dimbulah Region

A reminder that the Felix F-750 Produce Quality Meter is still available for use in the Mareeba / Dimbulah region.

Growers will be able to borrow the machine for **up to four hours** and conduct their own testing in the field. The meter comes with instructions on how to use the machine, and a copy of your readings will be sent to you within a week of testing (lot averages can be viewed in field when undertaking readings).

Please read all instructions carefully before using the machine and please take care not to drop the machine.

The meter has been left with local director Matt Fealy, who will keep a register of users and run basic maintenance on the machine. He can also offer basic support on how to use the machine.

If you would like to borrow the machine please contact Matt Fealy on 0402 412 471 or matt@blueskyproduce.com.au.

If there are any issues while you are using the machine, please contact Jessica or Samantha on (07) 3278 3755.

The project included farm readings from 9 regions visiting 91 farms, testing the four major varieties throughout the 131 visits collecting over 8,300 data sets. Whilst the data set shows that the project visited 9 regions, it should be noted that Carnarvon was visited by AMIA personnel throughout the season, however a machine was not available for use at the time. The machine was still undergoing calibration work on the east coast which coincided with pre-harvest and harvesting. It should also be noted that even though the project visited 91 farms, AMIA is aware that

more farms were using either privately owned NIR machines or those owned by the CQU, NTDPIR and WADPIR. It should also be noted that at grower requests other varieties outside the four major varieties were tested using the closest cultivar. This to provide growers a guide against their 'gut feel' for where they saw the maturity of the crop.

The visits to all regions commenced one month prior to the previous season (during project MG16002). Preseason crop forecasting highlighted an earlier than expected harvest plan and it was seen to commence two to three weeks earlier across most regions. The project collected over 8,300-point data sets (Appendix Three; B, C, F, G and I) and reported this back to each grower/manager/farm consultant as an average %DM for the block or orchard and for each variety tested. The maximum and minimum reading and standard deviation was also provided with each block assessed. This provided the participating grower with an indication of the fruit maturity and the range of maturities in the block. The data was collected and summarized in the attached results spreadsheet (Appendix Five).

Table A. Summary of farm visits, varieties and DM readings collected by project staff for MG17002

2018 (this season)					
Region	Farms Visited	Varieties	Period	Visits	Readings
Kununurra, WA	7	KP. R2E2	5/09/2017	7	n/a
Darwin, NT	15	KP. R2E2, Other	29/08/2017-4/10/2017	25	1540
Katherine, NT	6	KP, R2E2, Other	19/09/2017-5/10/2017	8	337
Bowen & Burdekin, Qld	25	HG, KP, R2E2,	11/10/2017-28/11/2017	43	3120
Mareeba Region, Qld	18	Calypso, HG, KP, R2E2, Other	2/11/2017-4/12/2017	23	2156
Bundaberg & Rockhampton	9	Calypso, HG, KP, R2E2	17/11/2017-10/01/2018	12	965
Northern NSW	1	HG	15/12/2017	1	44
Gingin, WA	10	KP. R2E2	7/02/2018-19/02/2018	12	174
9 regions	91	Calypso, HG, KP, R2E2, Other	29/08/2017-19/02/2018	131	8336

Outcomes

This season AMIA visited 91 farms, 30 new farms more than the previous season. AMIA staff made 131 visits to growers which totalled 28 more visits than the previous season. A total of 8,336 readings were conducted, 1,951 more readings on the previous season.

There was a lot of demand in the Bowen / Burdekin area for visits throughout the season based on the number of farm visits by region, however it should be noted that access to machines in other regions was supported with additional resources such as follows; Darwin – NT Farmers, Katherine – Nutrano (7Fields), Mareeba/Dimbulah – Matt Fealy at Blue Sky Produce (NTF06), Rockhampton/Yeppoon/Bundaberg regions – CQU, Kununurra – NT DPIR and Gingin – WADPIR. This season Carnarvon was the only region to miss the availability of the Felix machine for use. It was planned that the newly purchased WADPIR machine would be calibrated in time for the season however a delay in transit and access to seasonal fruit impacted on the readiness of the machine for this region. Next season, Carnarvon Growers association will be provided access of a machine early to support the growers. Varieties grown in this region include KP, R2E2, Calypso, Honey Gold.

This project (due to funding constraints) was unable to validate the Kiett model dry matter standard however growers were keen and did request we test the variety during on farm visits throughout the season. We also tested other varieties outside the four key varieties in the 2016 mango industry quality standards at the request of growers. It should also be noted that calypso and honey gold did not present a lot of readings. Growers of these varieties have their own machines or access to machines owned by other growers that they could borrow when required.

At the onset of the season one Felix 750 machine was purchased as a result of attending the preseason roadshow in Katherine 2017. Throughout the season two groups of growers and one wholesaler expressed interest in purchasing a machine. Currently there are over 20 machines in use. AMIA has on register a total of eighteen active machines that participate in the calibration process service provided by the CQU personnel.

Table B. Summary and comparison of %DM data collected in 2018 versus the previous year 2017

2018 (this season)			2017 (previous season)			2018 versus 2017						
Region	Farms Visited	Visits	Readings	Farms Visited	Visits	Readings	Difference on LY			% change on LY		
							Farms Visited	Visits	Readings	Farms Visited	Visits	Readings
Kununurra, WA	7	7	n/a	0	0	0	0					
Darwin, NT	15	25	1540	12	18	822	13	7	718	25%	39%	87%
Katherine, NT	6	8	337	6	12	574	2	-4	-237	0%	-33%	-41%
Bowen & Burdekin	25	43	3120	14	20	797	29	23	2323	79%	115%	291%
Mareeba Region, Q	18	23	2156	19	31	2547	4	-8	-391	-5%	-26%	-15%
Bundaberg & Rockhampton, Qld	9	12	965	8	19	1495	4	-7	-530	13%	-37%	-35%
Northern NSW	1	1	44	2	3	150	-1	-2	-106	-50%	-67%	-71%
Gingin, WA	10	12	174	n/a	n/a	n/a	12	10	174			
9 regions	91	131	8336	61	103	6385	30	28	1951	49%	27%	31%

Summary:

49% increase in orchards visited during the season,

27% increase in orchard visits,

31% increase in tests performed.

Monitoring and evaluation

(Refer to M&E Plan - Attachment 2)

During the 2017 season AMIA staff contacted growers approximately 3-4 weeks out from their initial forecast indications to set up farm visits to conduct NIR readings. Planning on farm visits weeks out from harvest helped growers with their harvest planning. This season AMIA also increased access to the machines by leaving them in regions with trained personnel so growers could book in visits outside the offered times of the AMIA staff. In the NT, growers had access to the NTF01 machine which was held at the NT Farmers office in Coolalinga. This machine was made available during the Queensland harvest and left with Matt Fealy in FNQ. The opportunity to leave the machine in Bowen Burdekin area was planned however an issue with a market machine meant this machine was required elsewhere for the period planned. AMIA's aim during the season was to instil confidence in the growers through encouraging them to use the machine themselves. The lessons learnt through leaving the machine in Mareeba at Matt Fealy from Blue Sky Produce was that it doesn't really encourage growers to use it. More training is required so the level of confidence is improved.

Objective reporting results that were unfavourable during the season was a good pretext to call growers and book them in for a farm visit with NIR testing included. It was a great way to introduce the machine and its capabilities to new growers who were not aware of the technology or were aware but had not had the opportunity to see the unit or it in action. Most of the new orchards we visited this season had one or two visits. This was enough to demonstrate the use of the NIR meters, introduce the technology and do a simple assessment of the blocks tested. The conversations were then about the possible scaling up for next season and how the farmers could factor the NIR meters into their next harvest planning cycle. It must be mentioned that fear of unfavourable DM results published for fruit that is sent to market continues to receive mixed reactions. It continues to demonstrate that there is a heightened awareness that the NIR %DM is being used as the industry measure of fruit maturity but not necessarily a confidence in the process by the grower.

The region with the most uptake this season was the Bowen and Burdekin region. Almost every farm visited engaged in multiple visits namely two to three visits, with one farm visited at least four times. Similarly, several farms in Mareeba were visited on three occasions and if not for a software failure would have engaged in four visits to aid the collection of trend data for evidence based planned harvests. Throughout the season some farms engaged in multiple visits but on different blocks, which made it hard to develop trend data especially when the first blocks tested were harvested before the return visit. Other growers only asked for a single visit to assess the fruit %DM. Most growers in this category were already familiar with the technology and used the on-farm visit to validate their judgement for where the crop maturity sat. Most of these growers then applied 0.7%DM per week accumulation (or 0.1%DM per day) to plan their harvest start date for their orchard. It was difficult to capture trend data from farms who only wished to engage in one visit prior to harvesting and return to test again to map trend data. The project allowed as many growers as possible to see and use the new technology. AMIA encouraged growers in regions to become familiar with the tool and the process.

In addition to using the NIR technology in field and as part of a separate project (MG15003 Data Collection to Facilitate Supply Chain Transparency – Stage 3), random consignments were tested with Felix 750 Produce Quality Meters in Sydney, Melbourne and Brisbane markets (different to on farm testing). This is part of a separate project (MG15003 Data Collection to Facilitate Supply Chain Transparency – Stage 3). These results of the market testing (also known as objective reporting) were provided to the Industry Development Manager and then tabulated for publishing in My Mango throughout the season (part of the communication program). This objective reporting process further engaged growers and other industry stakeholders. Growers initially asked for this process to take place, to hold all industry colleagues accountable to produce a good quality product and to discourage picking immature fruit. Now other industry stakeholders such as major retailers have embraced the technology and have aligned their specifications with the industry dry matter standards. The expectation is engagement is expected to increase in the future.

When any new technology rolls out across an industry there are often incidents and issues that are highlighted at different farms or regions that need to be addressed by those advocating the adoption of that technology. One example where the use of the NIR machine was used exclusively across several farms to develop maturity trends was in Mareeba. After the rollout of the preseason roadshows, which highlighted the uptake by retailers as presented by category management staff, one consultant for several farms expressed interest to purchase a machine. The added appeal to this group of growers was there is current work on developing an avocado model for the machine. The individual growers also produced avocados. Near the end of the season, one growers fruit of

this group received a rejection due to immaturity. It was noted that there had been significant amount a rain prior to that harvest and that they had also progressed from an initial spot pick to a final strip pick. An independent assessment of the fruit to retest samples of the stock rejected was directed. Whilst the NIR DM and independent Brix analysis outcomes namely supported the original rejected fruit readings, the experience sees the grower taking a more holistic approach next season with reference to in the decision to pick including monitoring weather events and validating actual manual DM results with the F750 readings.

The onset of the season there were growers who indicated they would like access to the NIR technology to assist with harvest decisions and planning. There were also growers who indicated that the idea of purchasing a meter of their own or within a cooperating group was appealing. A narrative of a phone call at the commencement of the WA season with a manager from a major large, international wholesale company who was interested in the technology is attached in the Appendix Four. Though the price of these meters has reduced over the years, it is still quite a substantial outlay, especially if you are only using it for one commodity. The attitudes displayed by the project participants range from very embracing to sceptical.

Consistency of readings with an individual quality meter continues to be a point of interest. Mango fruit have an irregular shape and the NIR technology is dependent on the assessment taking place on the similar part of the fruit each time. Mangoes also range in size and very immature or slender fruit can give a false high reading and is not appropriate to be assessed by this meter. This creates some uncertainty and is good reason why multiple readings on multiple fruit to create an average value for a block or orchard. Consistency of readings between NIR machines testing the same fruit at the same time also continues to be a topic of interest. The calibration process requires a high level of skill and understanding as well as the ongoing requirement to upload the calibrations and must be factored into the long-term use of this technology.

During the season an article was published in the Courier Mail, 28 October, 2017 (Appendix Three, D) in relation to quality and flavour. It stated, “Agronomists say farmers are being forced to put more effort into the shape and quality of fruit rather than being able to focus on making it taste better. Recent research has found strawberries, rockmelon and tomatoes top the list of fruit and vegetables losing flavour, while papaya and **mangoes were reported to be tasting better.**” Due to budget constraints, research to develop a minimum dry matter standard for Keitt and confirm the R2E2 Dry Matter standard is at the right level was removed from this project. AMIA also tested other varieties outside the four key varieties including Keitts at the request of growers. from this project with the intention for its inclusion in the new project MG17000 - Building Best Management Practice Capacity for the Australian Mango Industry.

Recommendations

Next season AMIA suggest placing regionally based Industry Development Officers (IDO) to help facilitate training with the growers in each of the regions. Part of the tools of trade for this IDO role will include a F750 Quality Produce machine. This will offer growers better access to the NIR meter to move to evidence-based, block by block harvest plans. The accumulation of trend data of the blocks and the variation of fruit maturity in a block requires at least weekly access to the NIR machine for a period of at least two to four hours (orchard size dependent) to generate enough data to be statistically valid.

It is also recommended all machines used in field for On Farm Quality testing using NIR and Data Collection to Facilitate Supply Chain Transparency be serviced by Felix. We have recommended relevant maintenance applications to Felix as well.

The barriers as to why the instrument is not part of farm management;

1. Unit costs are \$10,000 and upward as well as current ongoing calibration costs. These annual calibrations need to be done on each unit for each variety each year. For most of our growers it is a prohibitive cost when the unit is only used for a few times each season. It is much more efficient to provide access to this equipment via our IDO roles.
2. To deliver consistent accurate outcomes there is a degree of training and operator skill required to use the units and again for a few usages each season for many growers the risk of getting inaccurate measurements is best offset by providing the service by IDO's.
3. Despite a number of years of customers including minimum DM as part of their specifications, there is still a degree of thinking by many growers and wholesalers that this requirement will all go away. Without the IDO's actively offering the service, many growers would continue to harvest without the necessary decision to pick information. Changing culture and behaviour is a slow process. Continuous reinforcement through our communications e.g. roadshows, newsletters is getting the message across slowly but there is still much more work to be done.

Australia's leading retailer has invested in the technology for the 2018/19 mango season by purchasing their own machine. They have engaged the leading Australian service provider Rudge Produce Systems to provide NIR testing at each of their distribution centres (DC).

The retailer has further endorsed the industry minimum dry matter standards by including the minimum dry matter standards and industry developed quality specifications as part of the mango quality specification requirement upon receipt to DCs Australia wide.

The continued investment of Australia's leading retailer highlights the continued endorsement of the technology. This endorsement which will be further communicated at upcoming 2018/19 preseason roadshows, would encourage growers to take the initiative and included dry matter testing as part of their on-farm practices. It was indicated in season 2017/18 by some growers they intended to purchase a machine, at a shared cost and share throughout the group. These growers noted that an avocado model could be an additional option and that as they grow both crop the tool would have further long-term benefits. Australian Mangoes has supported CQU in the development of initial avocado calibrations over the avocado season in early 2018.

Refereed scientific publications

None to report.

References

Walsh K, Subedi P, Owens G, 2007, 'Prediction of mango eating quality at harvest using short wave infra-red spectrometry', *Post-harvest Biology and Technology Journal*, Vol. 43, No. 3

Intellectual property, commercialisation and confidentiality

No project IP, project outputs, commercialisation or confidentiality issues to report.

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NT Farmers

WADPIR personnel

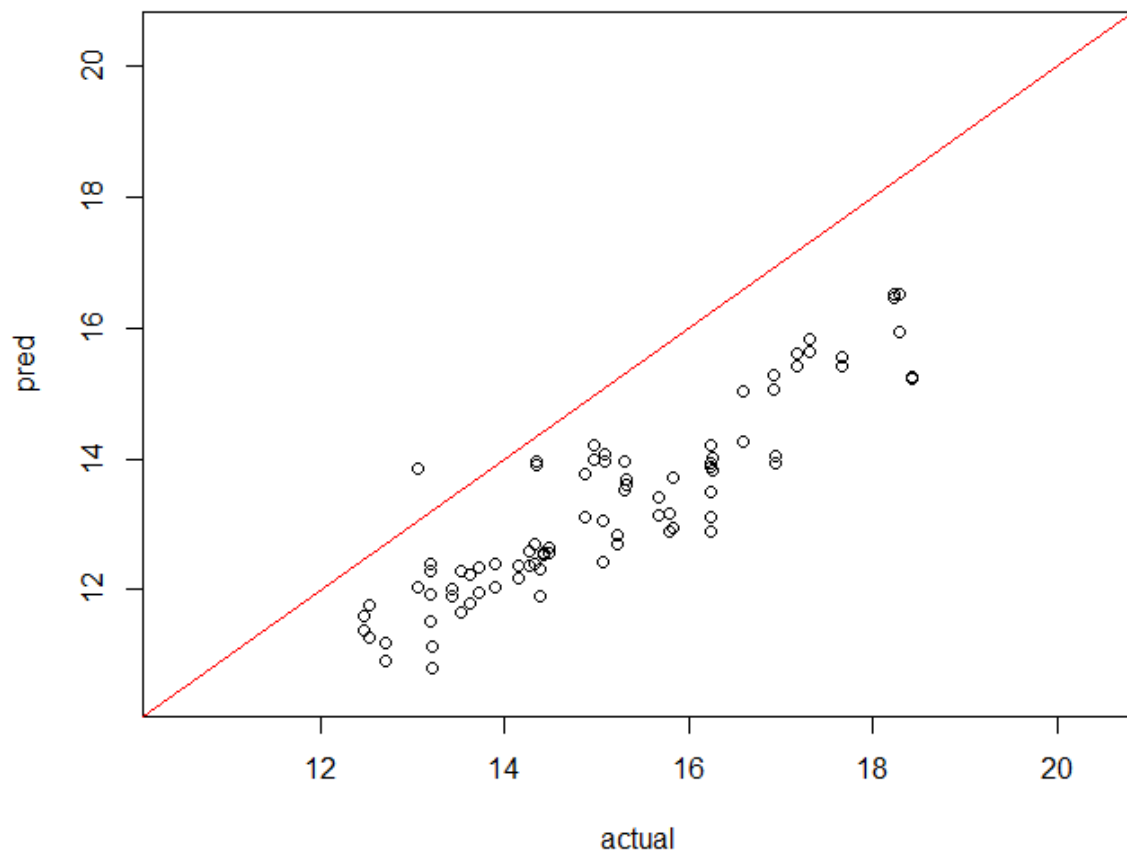
Appendices

- Appendix 1 – Calibration results 17 December 2017
- Appendix 2 – M&E Plan
- Appendix 3 - Supporting pictures
- Appendix 4 – Narrative from manager of a large, international wholesale company
- Appendix 5 – Summary spreadsheet of NIR visits and results
- Appendix 6 – Table summary of the spreadsheet of NIR visits and results

KP

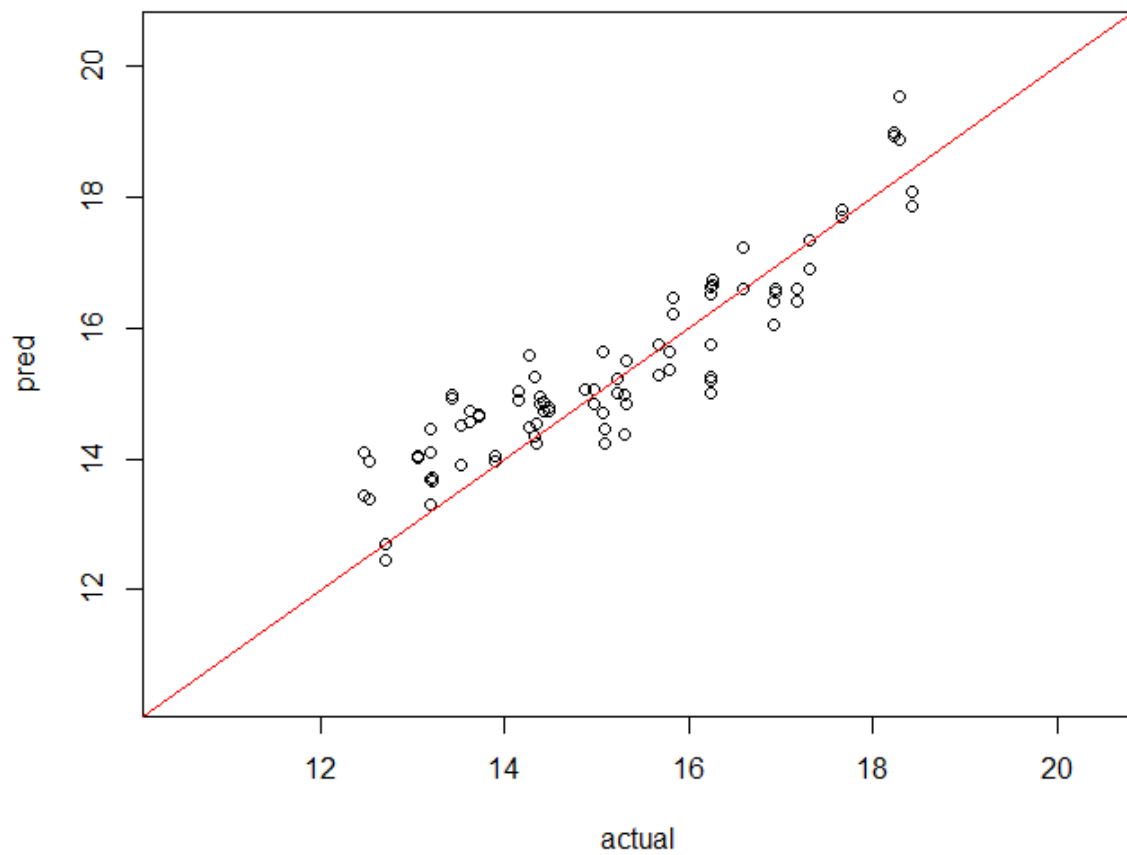
14002 AMIA 9

[1] "Bias: -1.82 R2: 0.82 RMSE: 1.95 SEP: 0.7 Average of population: 15.11
Standard Deviation of population: 1.64 Population sample number: 84 and a
range of: 12.47-18.43"



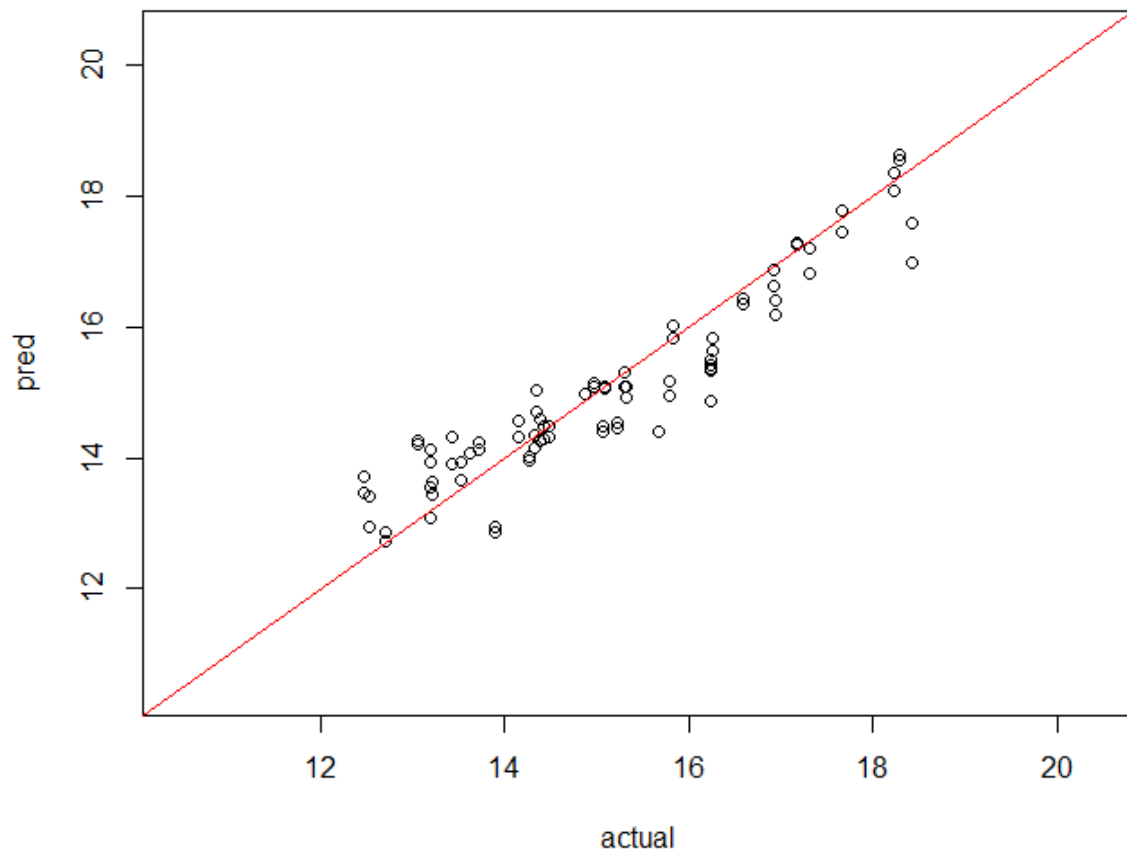
15006 CQU

[1] "Bias: 0.24 R2: 0.84 RMSE: 0.69 SEP: 0.65 Average of population: 15.11
Standard Deviation of population: 1.64 Population sample number: 84 and a
range of: 12.47-18.43"



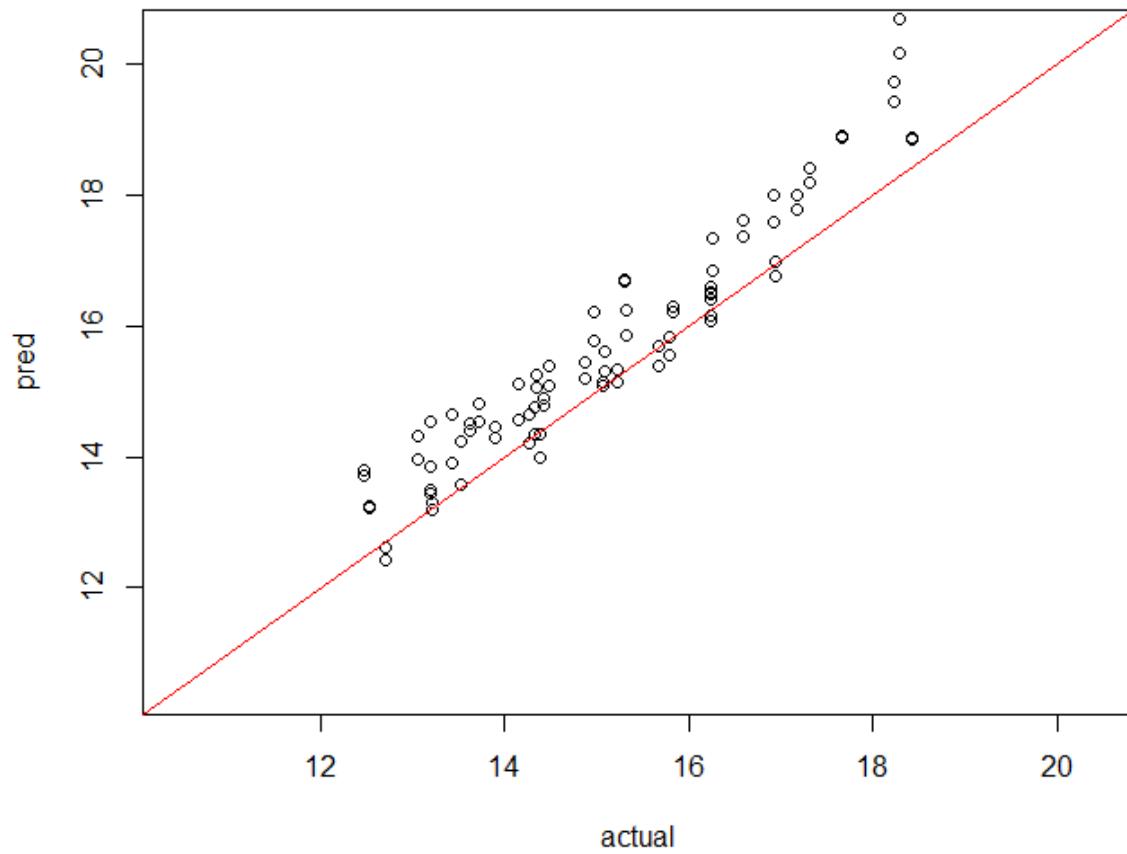
15014 AMIA 7

[1] "Bias: -0.07 R2: 0.87 RMSE: 0.6 SEP: 0.59 Average of population: 15.11
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range of: 12.47-18.43"



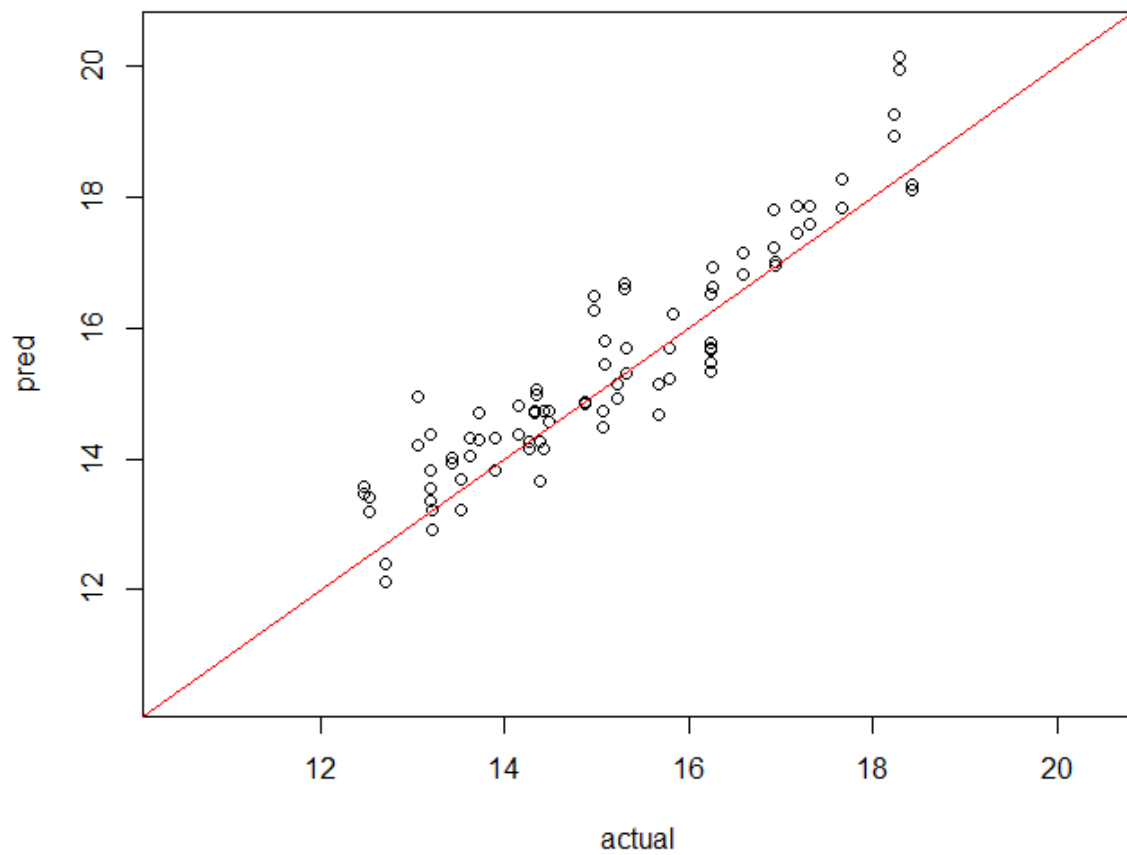
15015 RUDGE

[1] "Bias: 0.59 R2: 0.92 RMSE: 0.79 SEP: 0.53 Average of population: 15.11
Standard Deviation of population: 1.64 Population sample number: 84 and a
range of: 12.47-18.43"



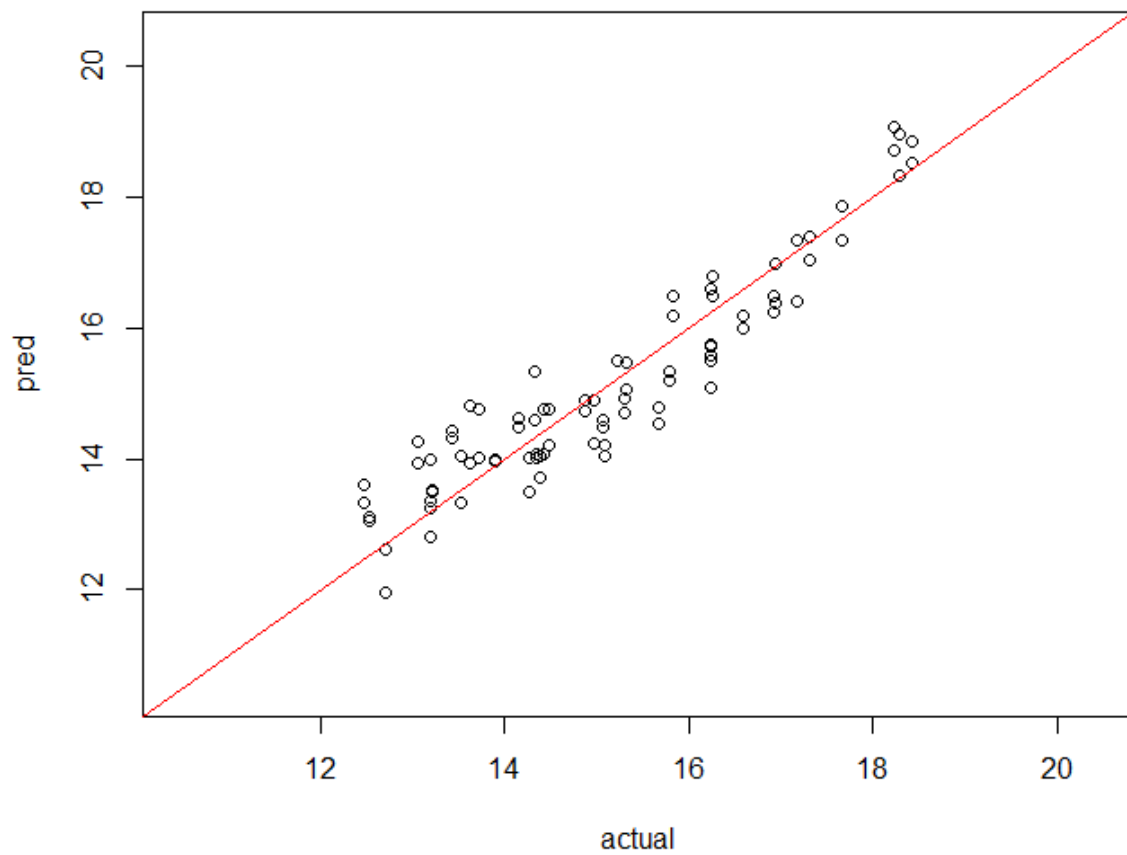
15038 AMIA 8

[1] "Bias: 0.31 R2: 0.87 RMSE: 0.69 SEP: 0.62 Average of population: 15.11
Standard Deviation of population: 1.64 Population sample number: 84 and a
range of: 12.47-18.43"



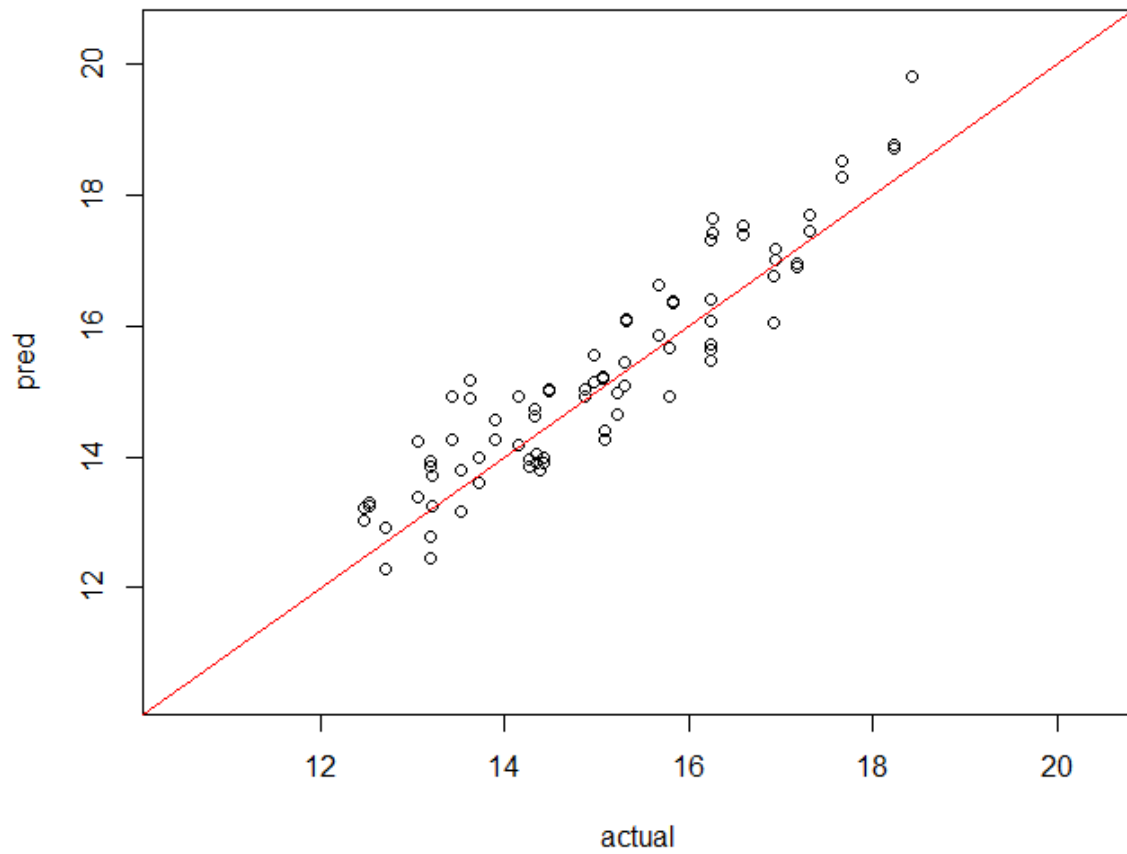
16041 NTFA

[1] "Bias: 0.01 R2: 0.87 RMSE: 0.58 SEP: 0.58 Average of population: 15.11
Standard Deviation of population: 1.64 Population sample number: 84 and a
range of: 12.47-18.43"



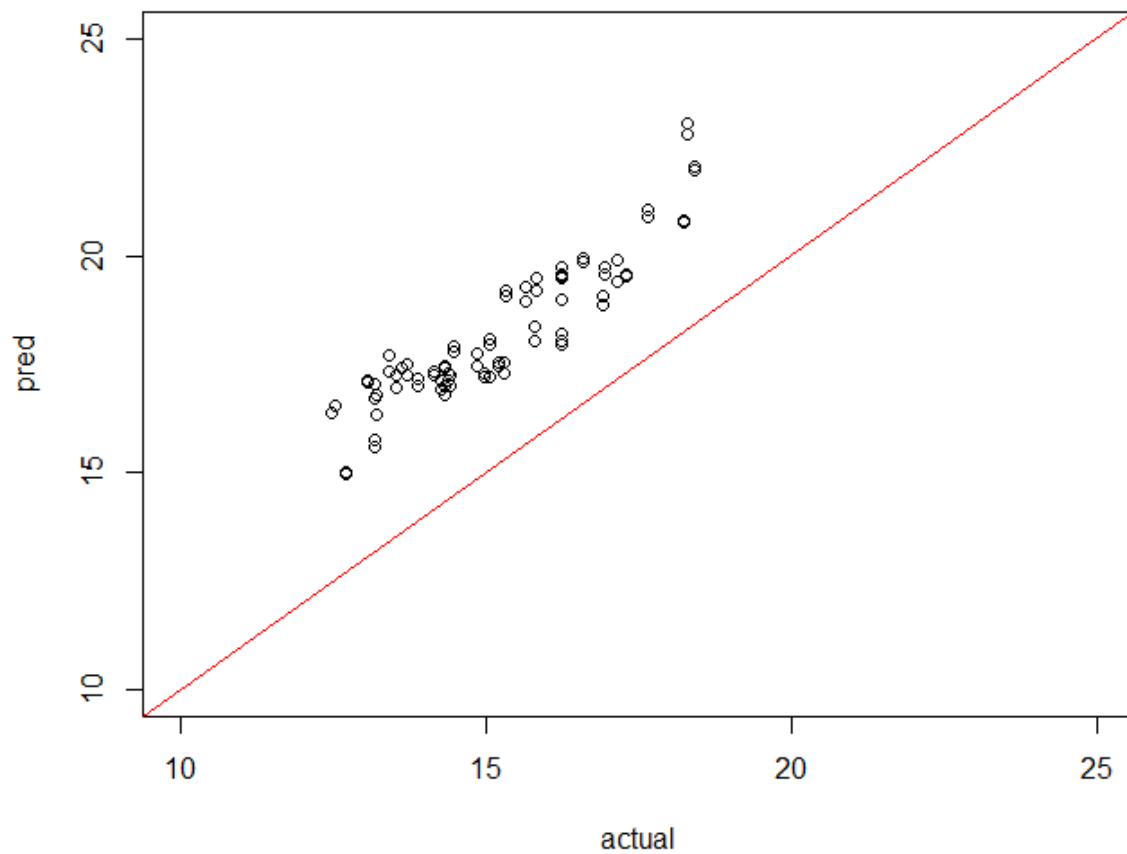
17040 CHAVE

[1] "Bias: 0.32 R2: 0.85 RMSE: 0.83 SEP: 0.77 Average of population: 15.11
Standard Deviation of population: 1.64 Population sample number: 84 and a
range of: 12.47-18.43"



17052 KUNANNARA?

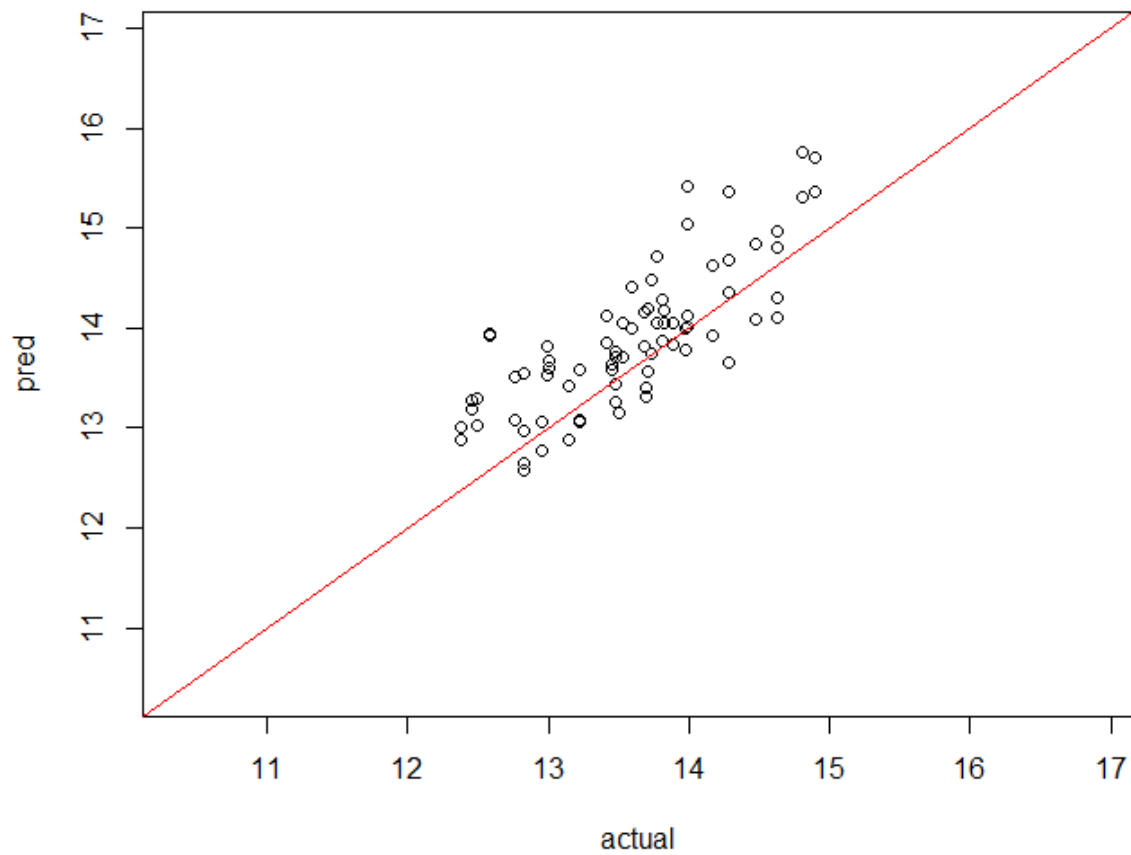
[1] "Bias: 3.04 R2: 0.83 RMSE: 3.12 SEP: 0.68 Average of population: 15.11
Standard Deviation of population: 1.64 Population sample number: 84 and a
range of: 12.47-18.43"



HG

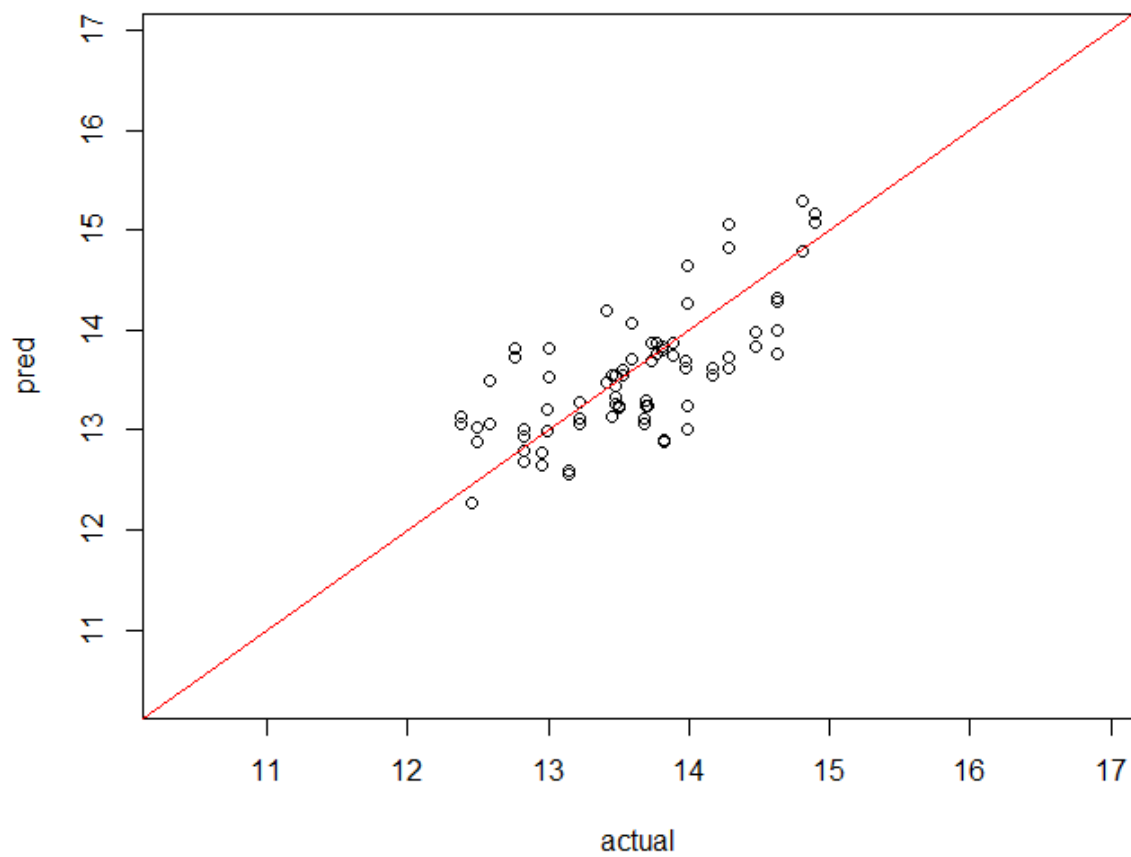
14002 AMIA 9

[1] "Bias: 0.3 R2: 0.62 RMSE: 0.54 SEP: 0.45 Average of population: 13.58
Standard Deviation of population: 0.66 Population sample number: 78 and a
range of: 12.38-14.9"



15006 CQU

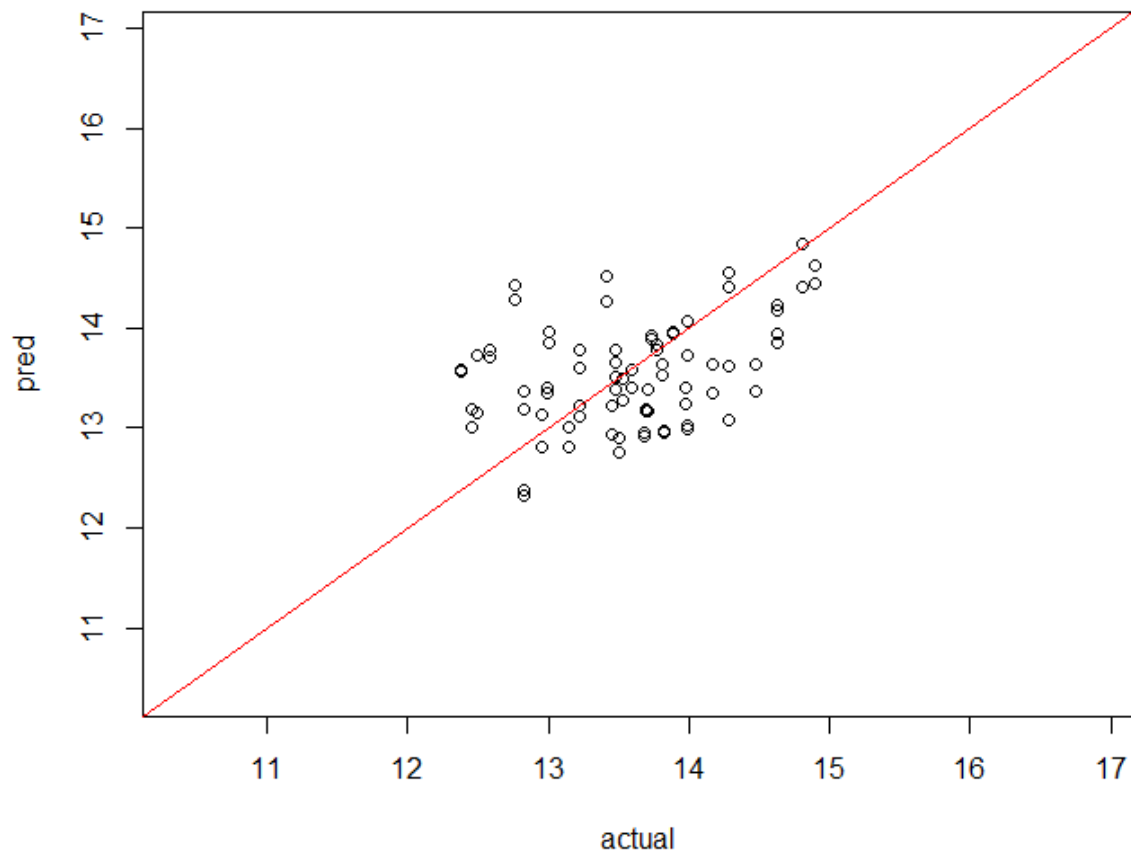
[1] "Bias: -0.05 R2: 0.53 RMSE: 0.48 SEP: 0.48 Average of population: 13.58 Standard Deviation of population: 0.66 Population sample number: 78 and a range of: 12.38-14.9"



15014 AMIA 7

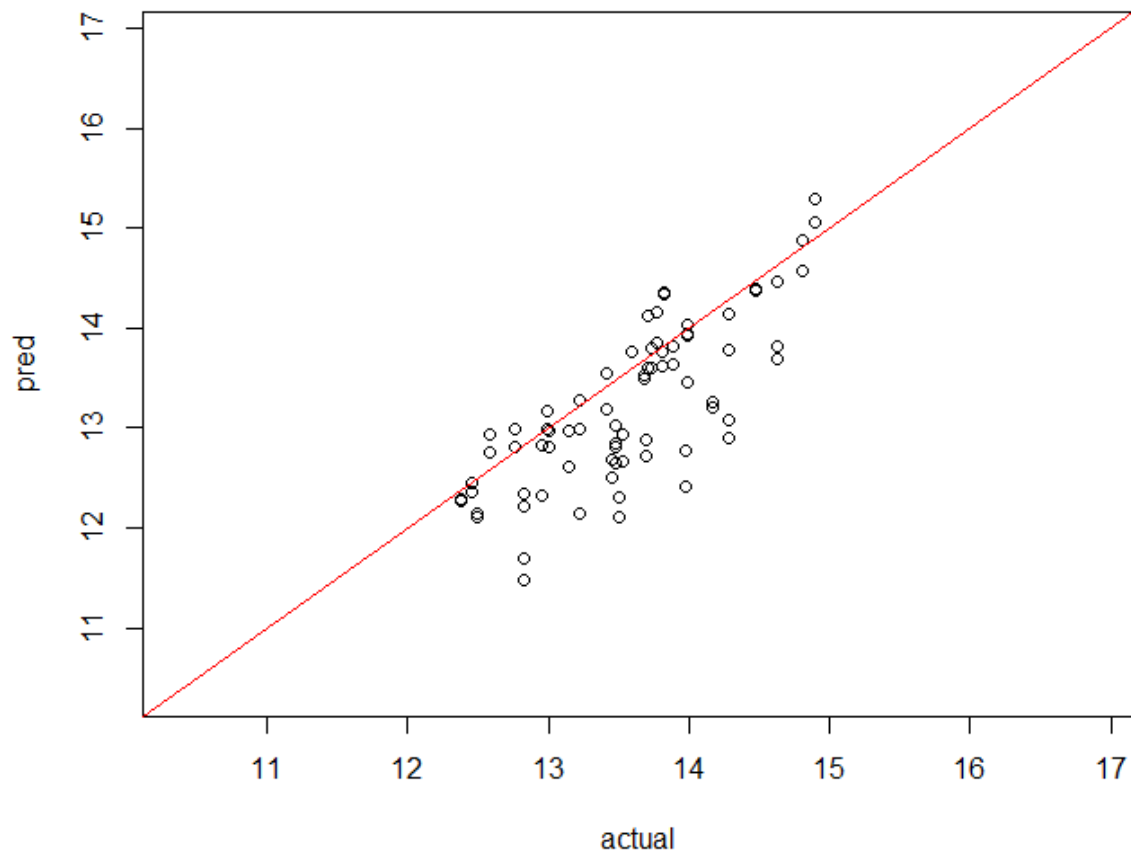
[1] "Bias: -0.03 R2: 0.16 RMSE: 0.65 SEP: 0.65 Average of population: 13.58 Standard Deviation of population: 0.66 Population sample number: 78 and a range of: 12.38-14.9"

OLD MODEL!



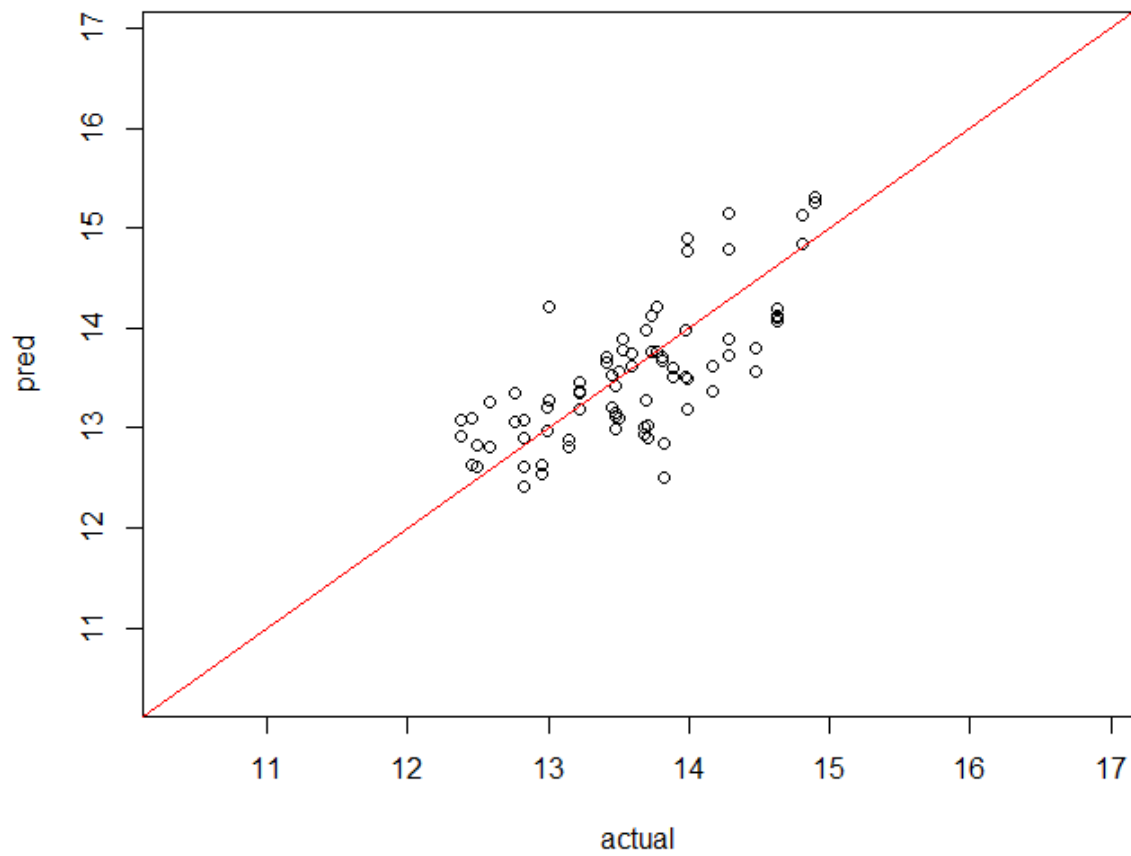
15015 RUDGE

[1] "Bias: -0.35 R2: 0.6 RMSE: 0.62 SEP: 0.51 Average of population: 13.58
Standard Deviation of population: 0.66 Population sample number: 78 and a
range of: 12.38-14.9"



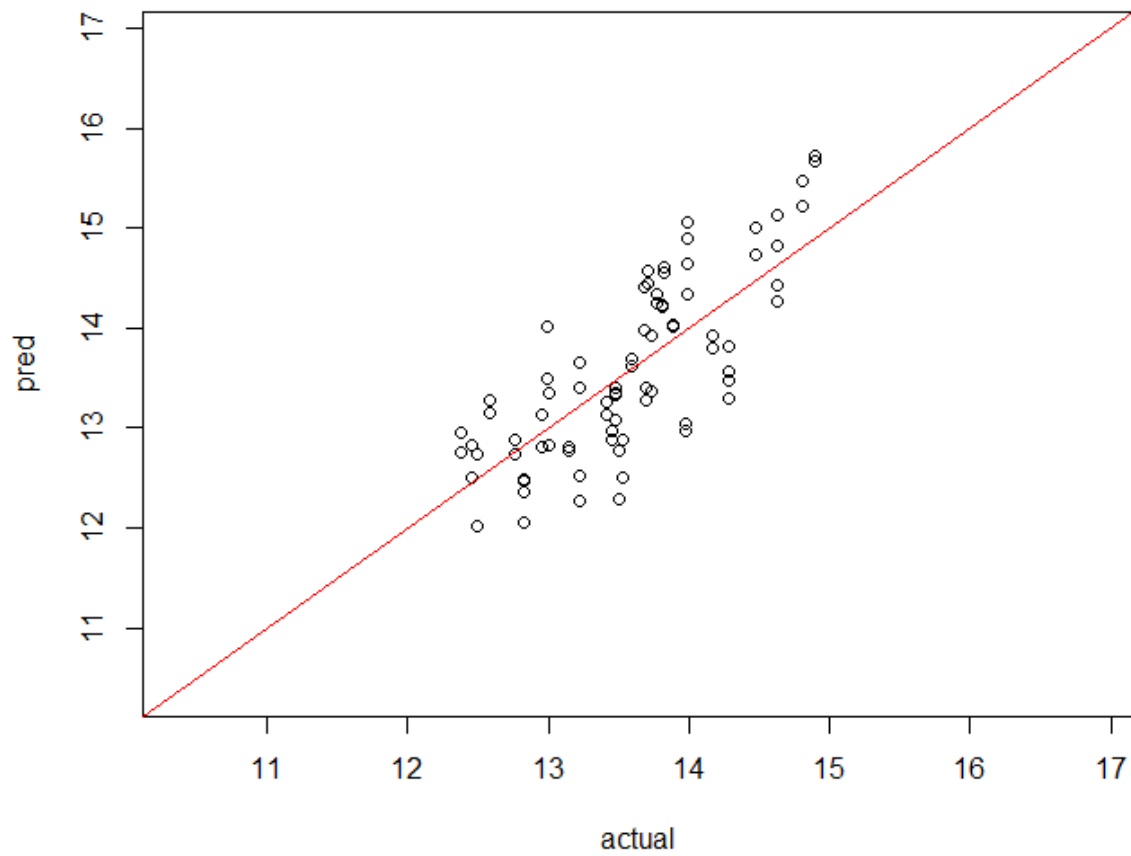
15029 Pinata

[1] "Bias: -0.06 R2: 0.53 RMSE: 0.49 SEP: 0.49 Average of population: 13.58 Standard Deviation of population: 0.66 Population sample number: 78 and a range of: 12.38-14.9"



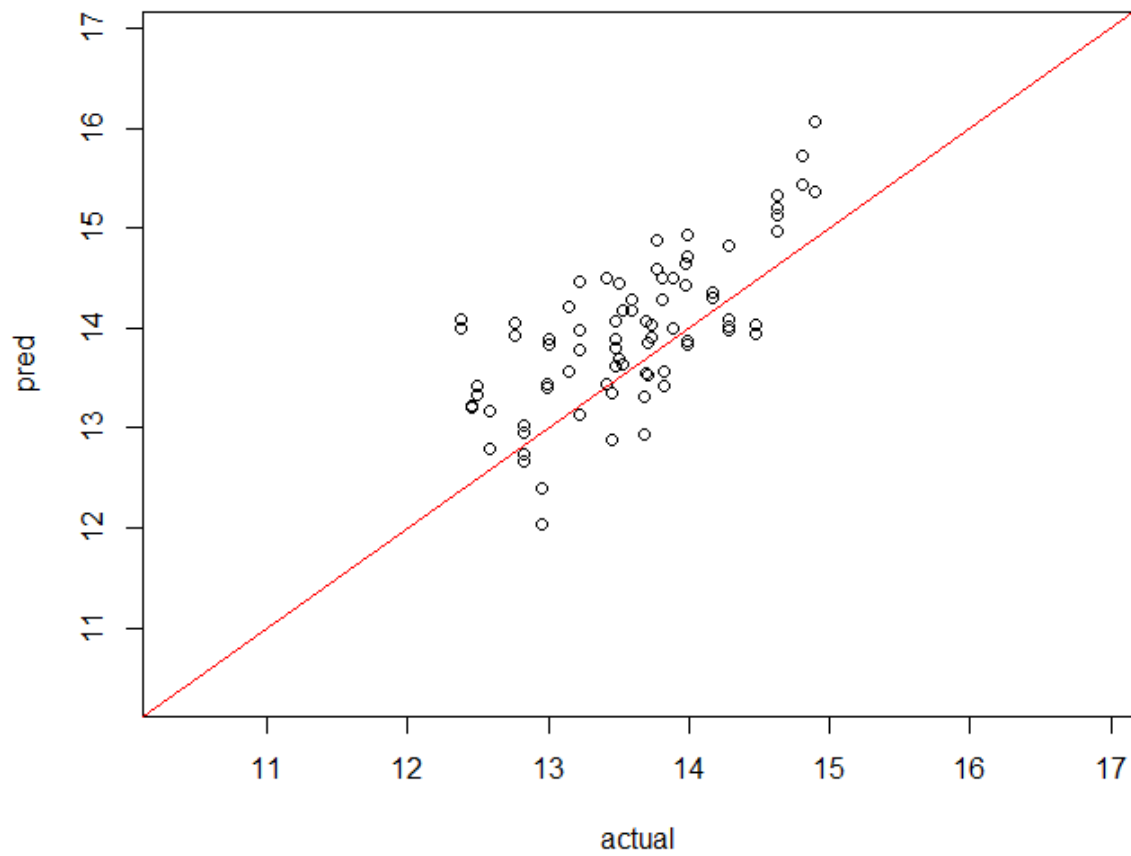
15038 AMIA 8

[1] "Bias: 0.02 R2: 0.61 RMSE: 0.56 SEP: 0.56 Average of population: 13.58
Standard Deviation of population: 0.66 Population sample number: 78 and a
range of: 12.38-14.9"



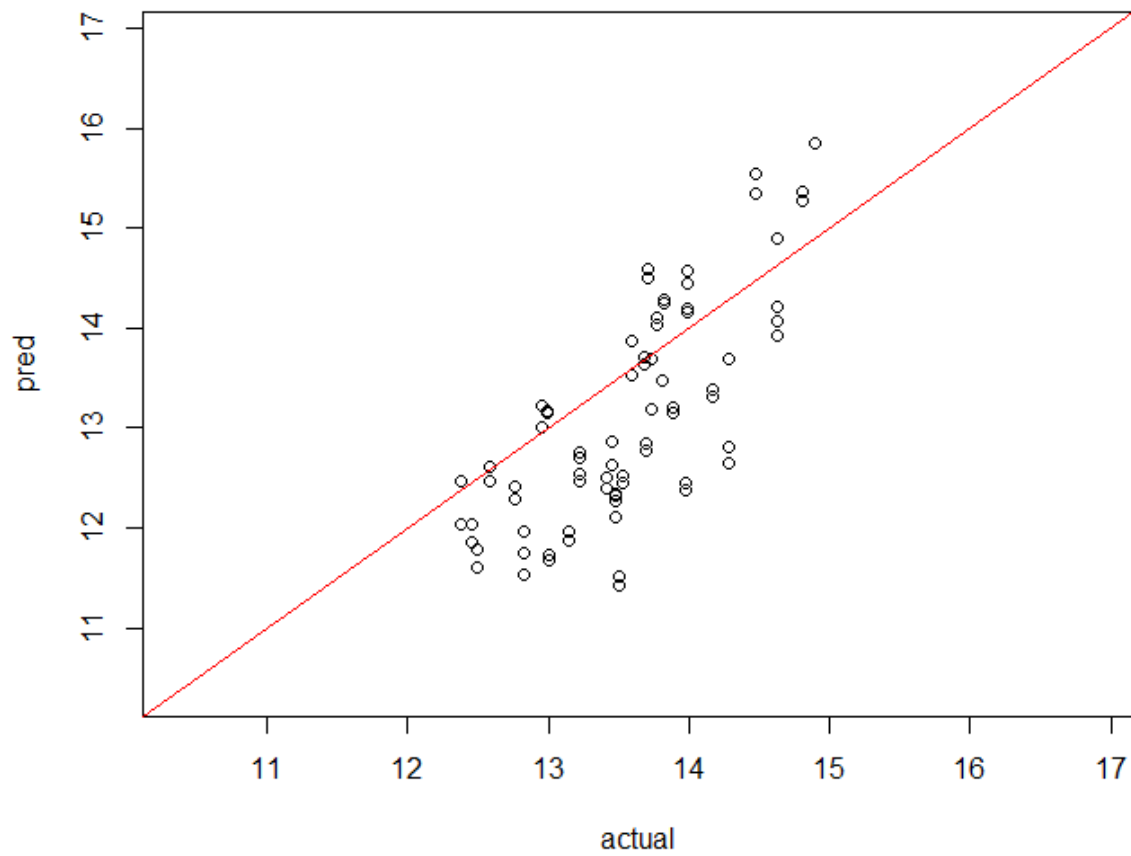
16041 NTFA

[1] "Bias: 0.38 R2: 0.51 RMSE: 0.66 SEP: 0.54 Average of population: 13.58
Standard Deviation of population: 0.66 Population sample number: 78 and a
range of: 12.38-14.9"



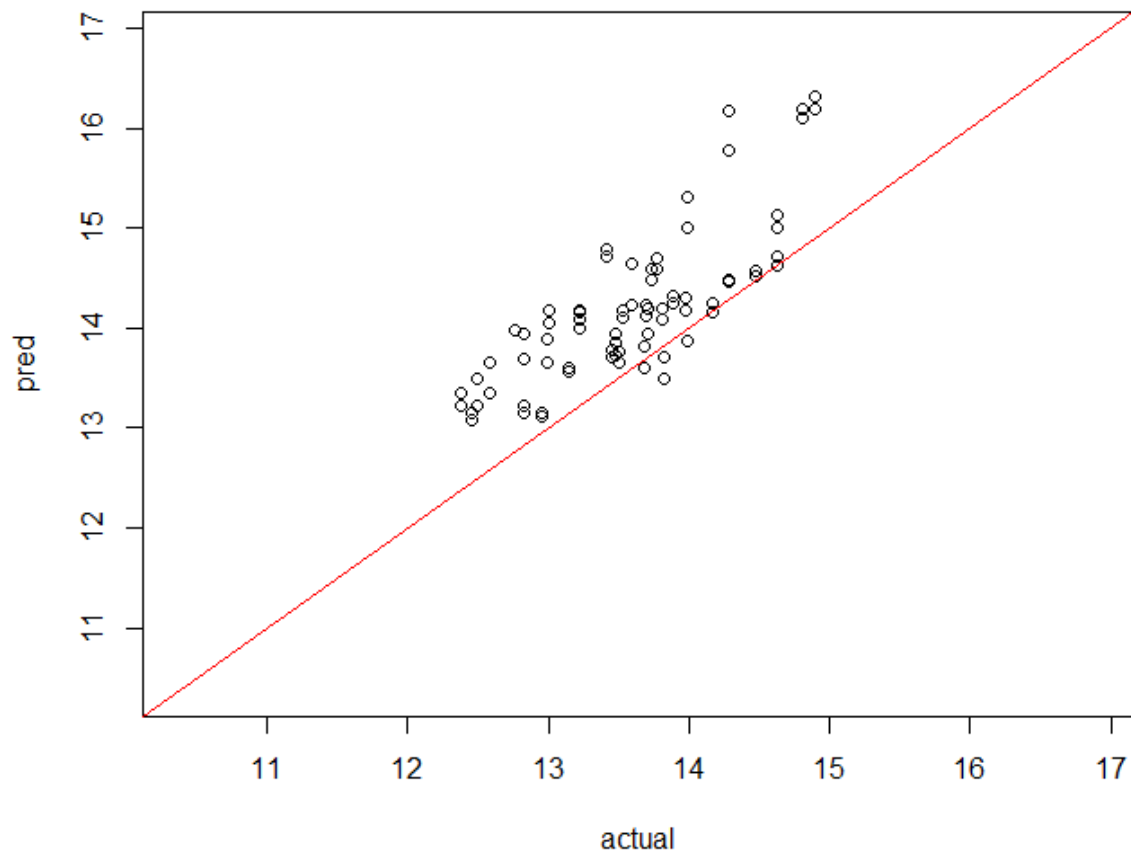
17040 CHAVE

[1] "Bias: -0.44 R2: 0.6 RMSE: 0.86 SEP: 0.73 Average of population: 13.58
Standard Deviation of population: 0.66 Population sample number: 78 and a
range of: 12.38-14.9"



17052 KUNANNARA?

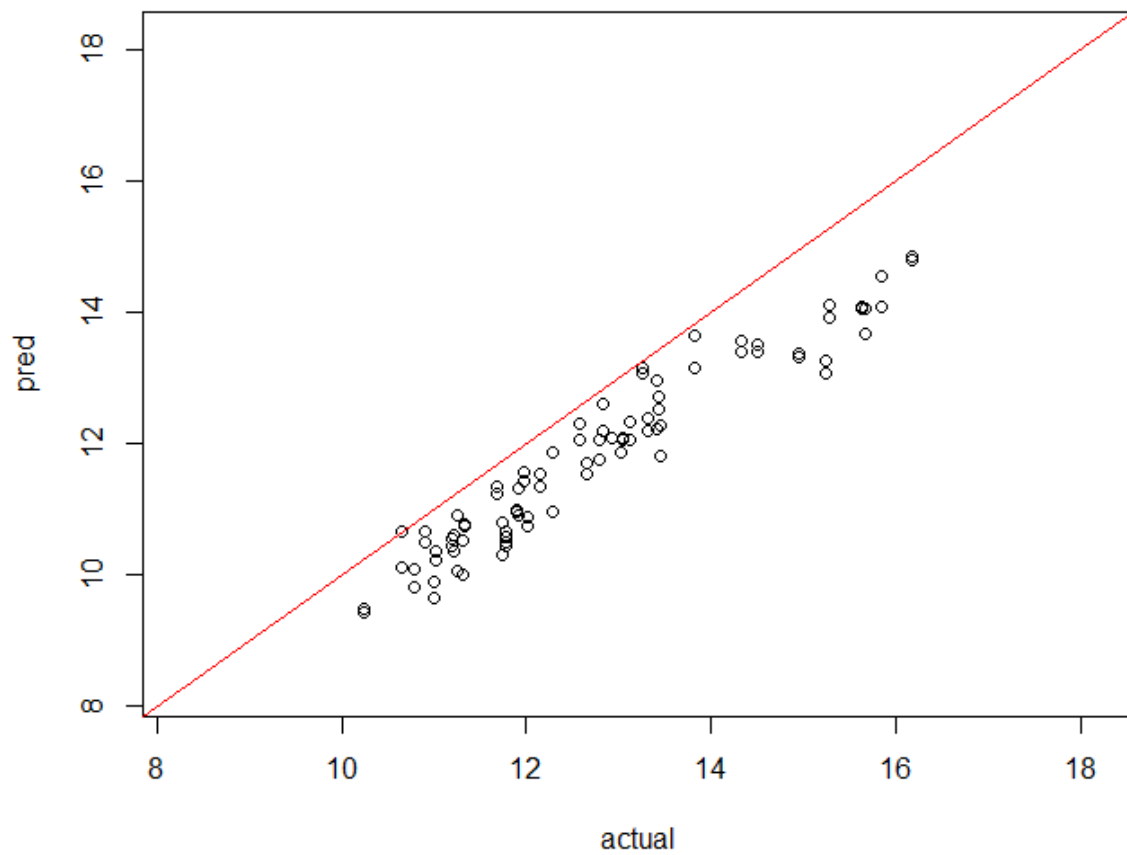
[1] "Bias: 0.61 R2: 0.62 RMSE: 0.77 SEP: 0.46 Average of population: 13.58
Standard Deviation of population: 0.66 Population sample number: 78 and a
range of: 12.38-14.9"



CALY

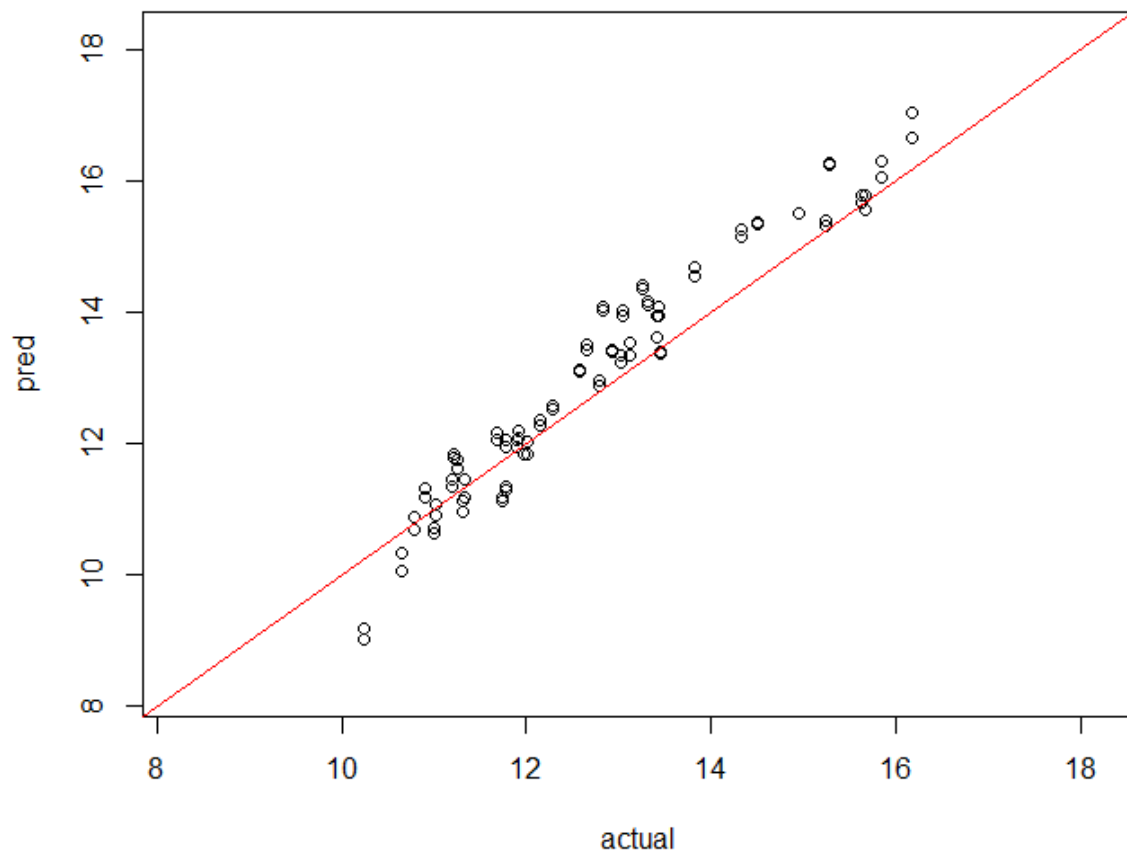
14002 AMIA 9

[1] "Bias: -0.94 R2: 0.93 RMSE: 1.04 SEP: 0.44 Average of population: 12.76 Standard Deviation of population: 1.57 Population sample number: 88 and a range of: 10.25-16.17"



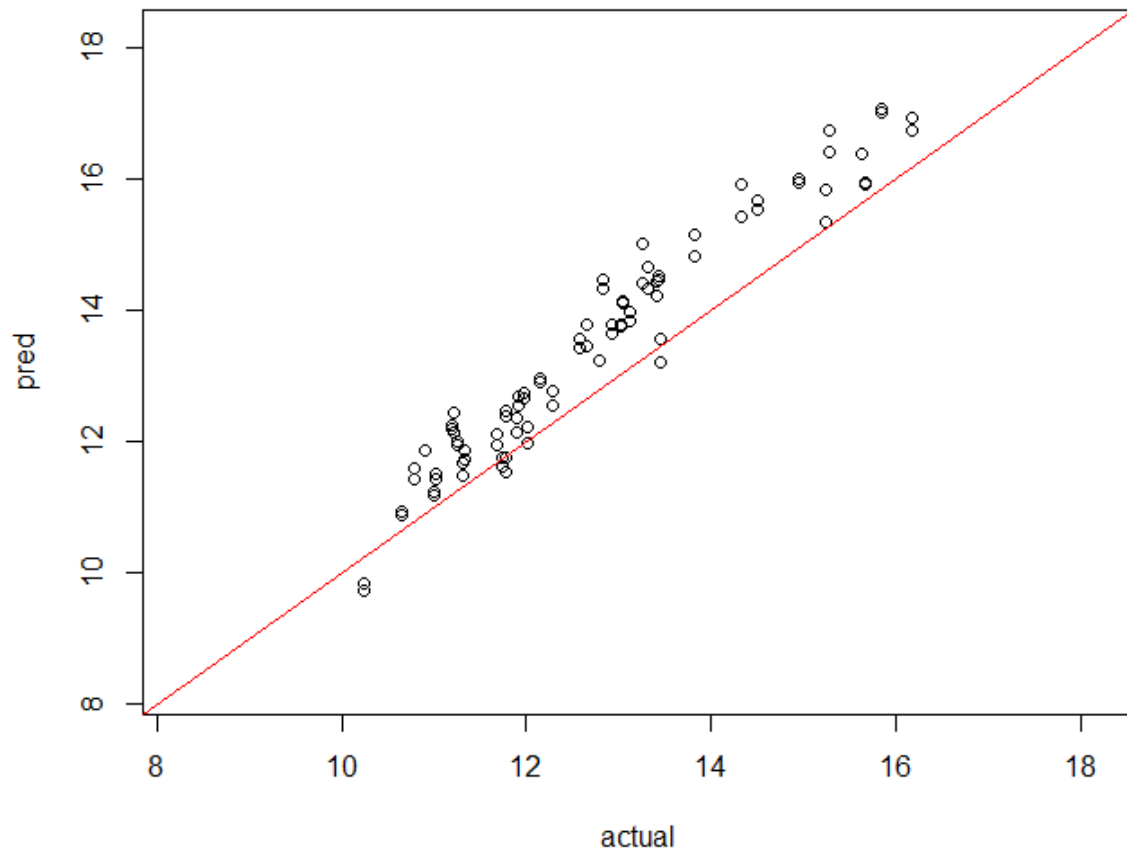
15006 CQU

[1] "Bias: 0.28 R2: 0.95 RMSE: 0.56 SEP: 0.48 Average of population: 12.76
Standard Deviation of population: 1.57 Population sample number: 88 and a
range of: 10.25-16.17"



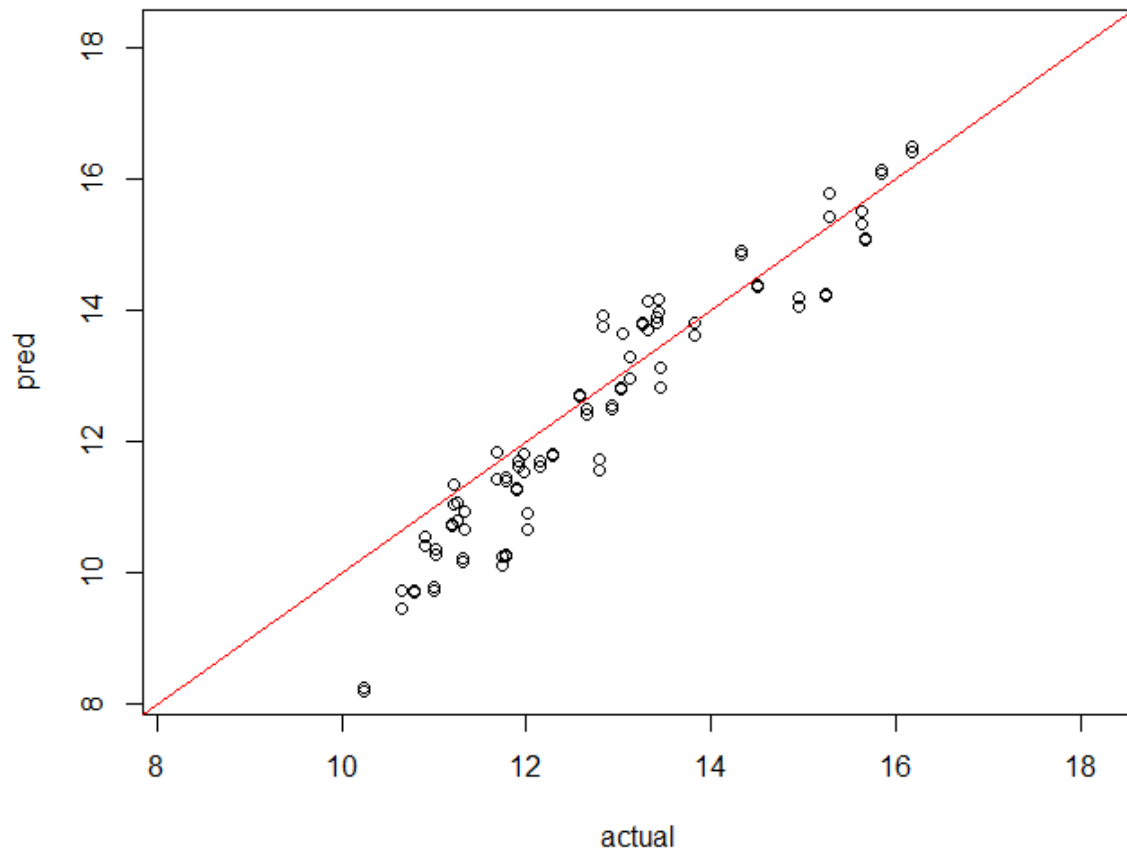
15014 AMIA 7

[1] "Bias: 0.7 R2: 0.94 RMSE: 0.84 SEP: 0.46 Average of population: 12.76
Standard Deviation of population: 1.57 Population sample number: 88 and a
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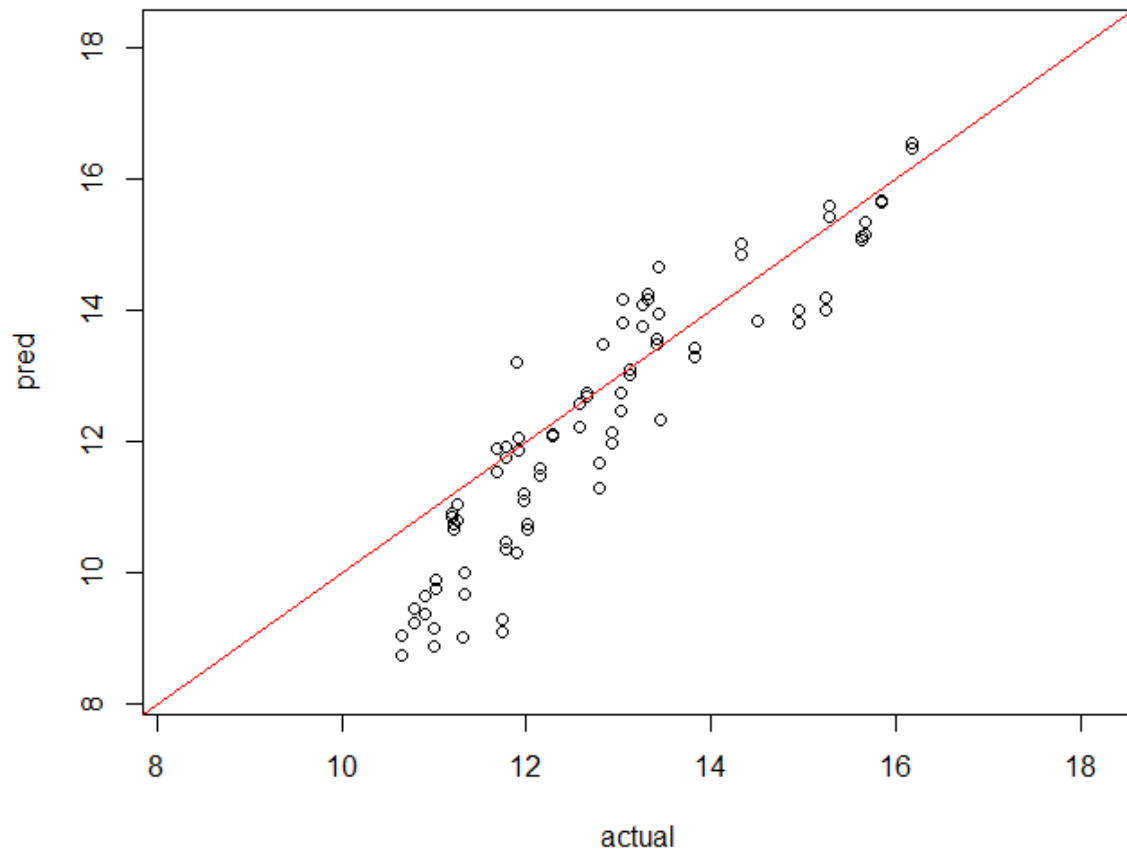
15015 RUDGE

[1] "Bias: -0.36 R2: 0.91 RMSE: 0.76 SEP: 0.67 Average of population: 12.76 Standard Deviation of population: 1.57 Population sample number: 88 and a range of: 10.25-16.17"



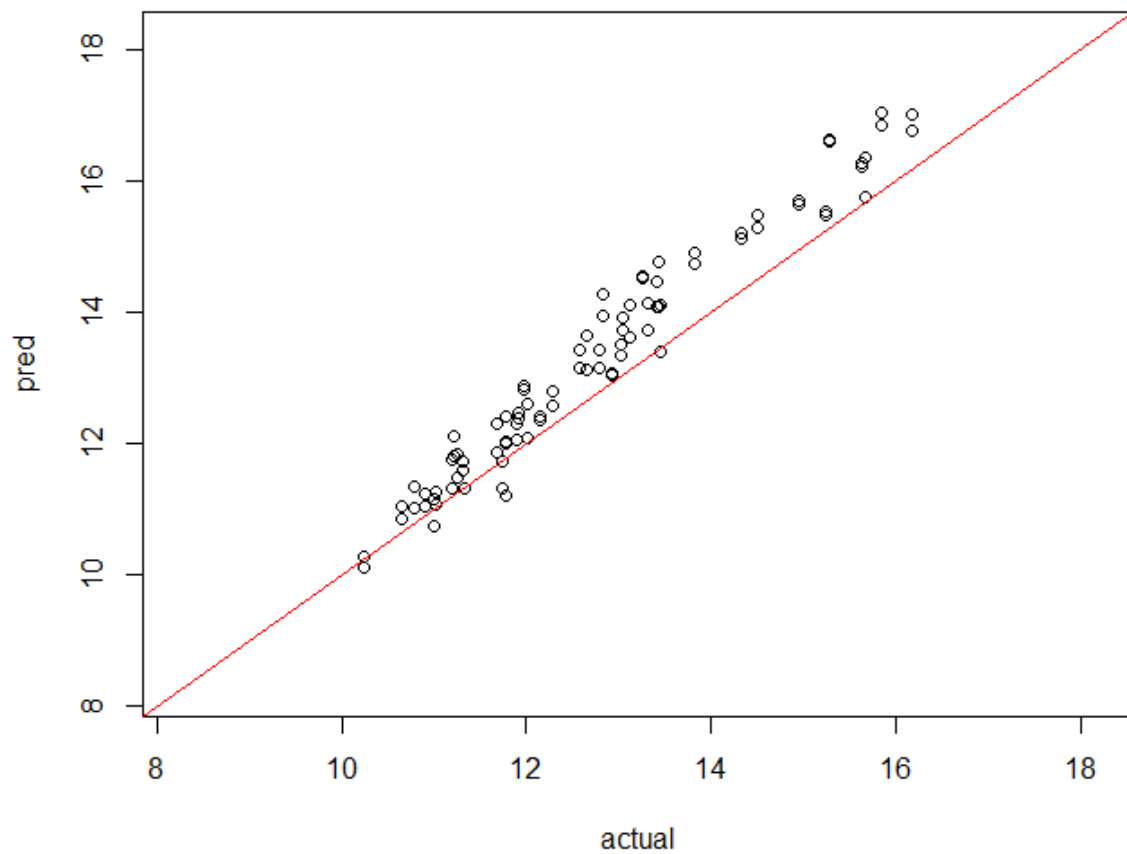
15038 AMIA 8

[1] "Bias: -0.59 R2: 0.84 RMSE: 1.14 SEP: 0.98 Average of population: 12.76 Standard Deviation of population: 1.57 Population sample number: 88 and a range of: 10.25-16.17"



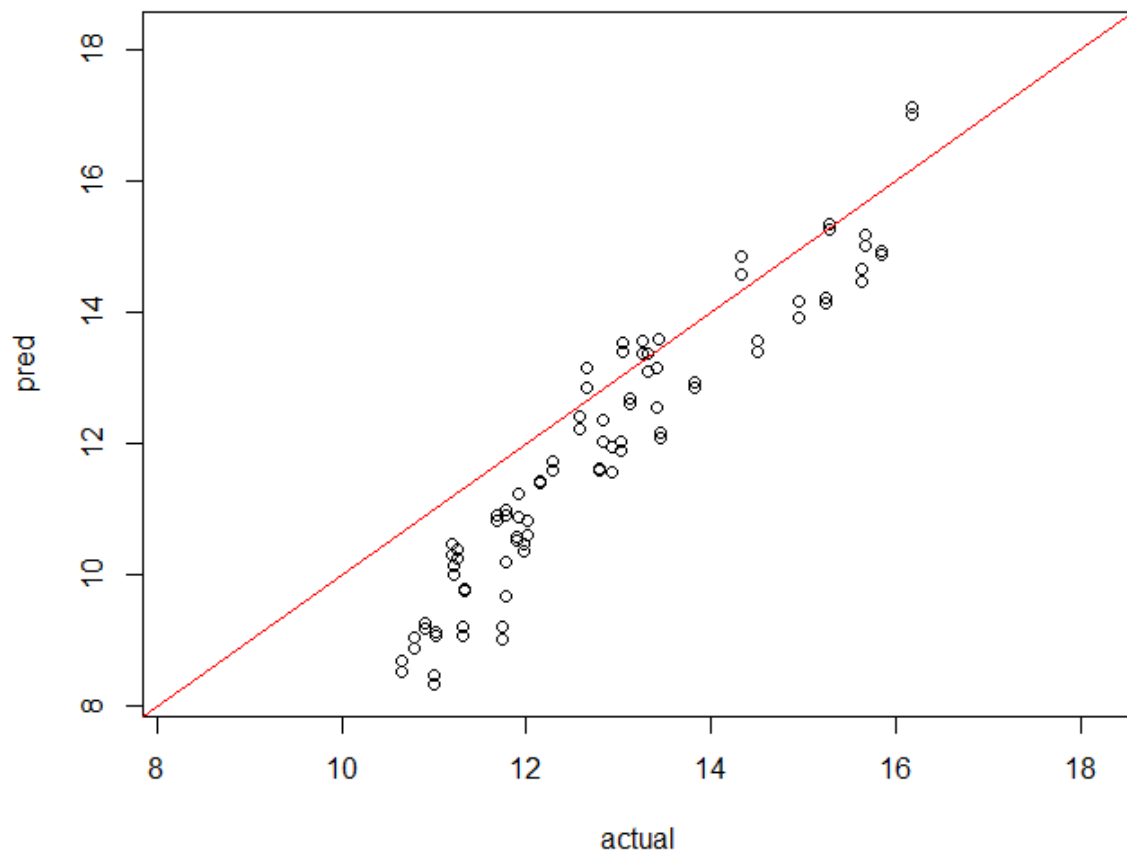
16041 NTFA

[1] "Bias: 0.53 R2: 0.96 RMSE: 0.67 SEP: 0.41 Average of population: 12.76
Standard Deviation of population: 1.57 Population sample number: 88 and a
range of: 10.25-16.17"



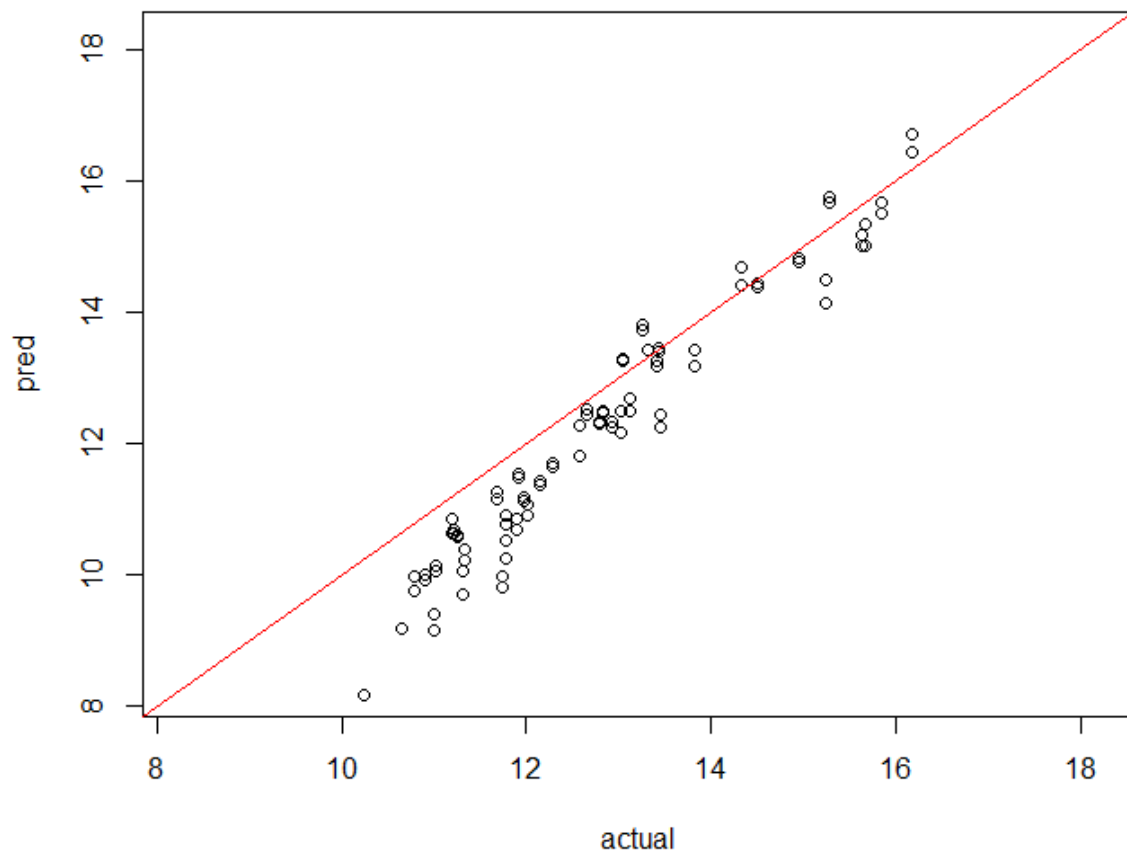
17040 CHAVE

[1] "Bias: -0.99 R2: 0.89 RMSE: 1.33 SEP: 0.89 Average of population: 12.76 Standard Deviation of population: 1.57 Population sample number: 88 and a range of: 10.25-16.17"



17052 KUNANNARA?

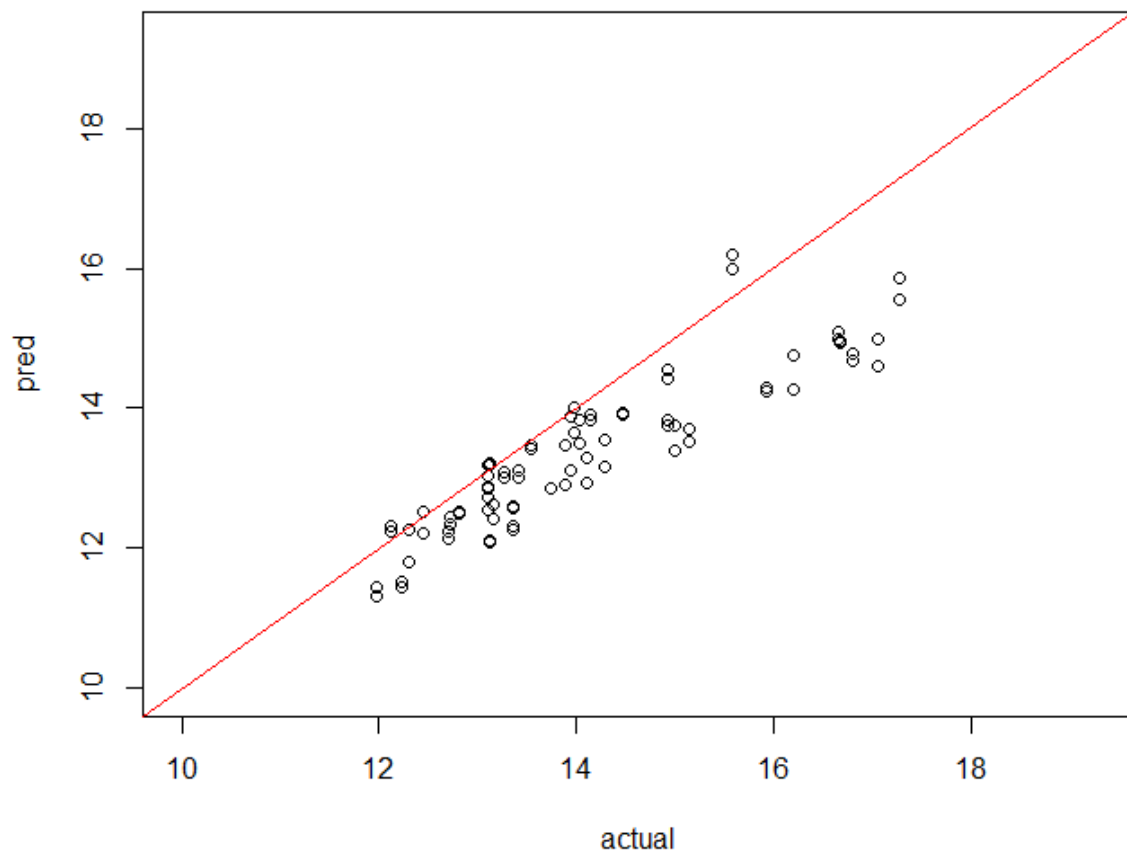
[1] "Bias: -0.62 R2: 0.94 RMSE: 0.87 SEP: 0.61 Average of population: 12.76 Standard Deviation of population: 1.57 Population sample number: 88 and a range of: 10.25-16.17"



R2E2

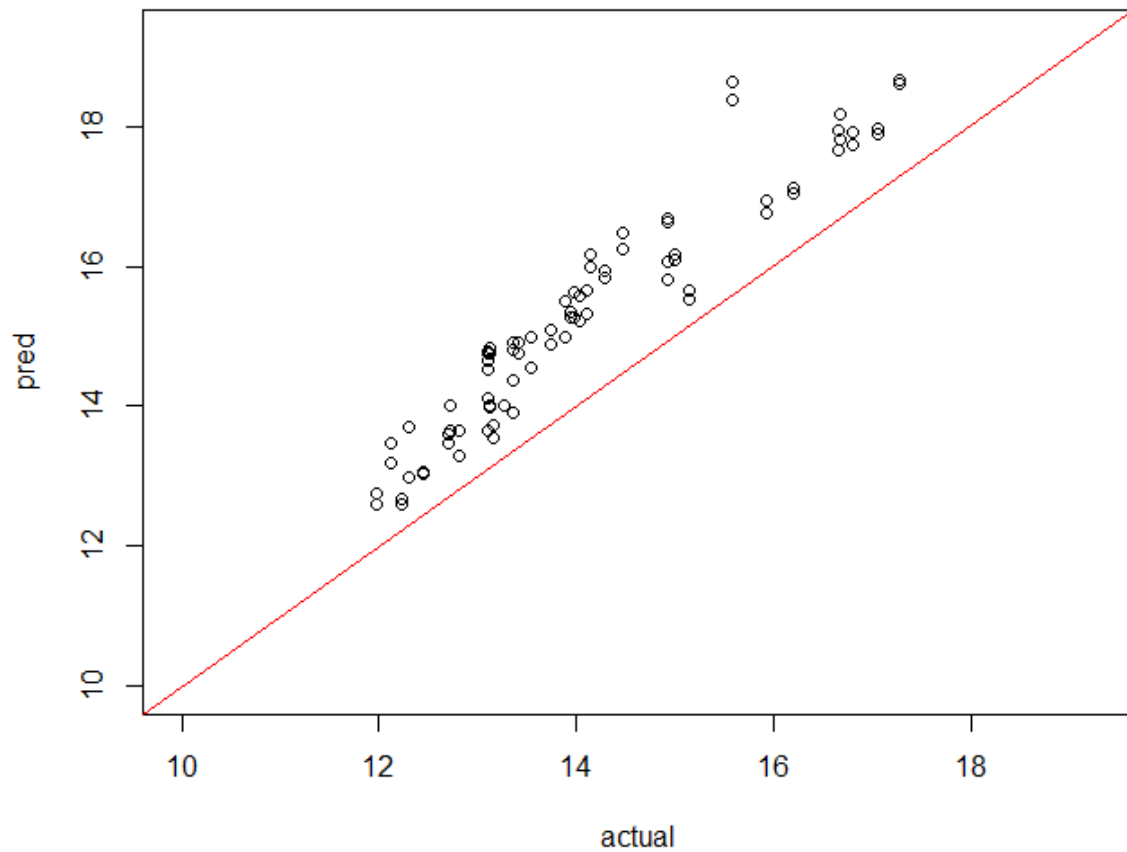
14002 AMIA 9

[1] "Bias: -0.73 R2: 0.82 RMSE: 0.99 SEP: 0.66 Average of population: 14.1
Standard Deviation of population: 1.46 Population sample number: 80 and a
range of: 11.98-17.28"



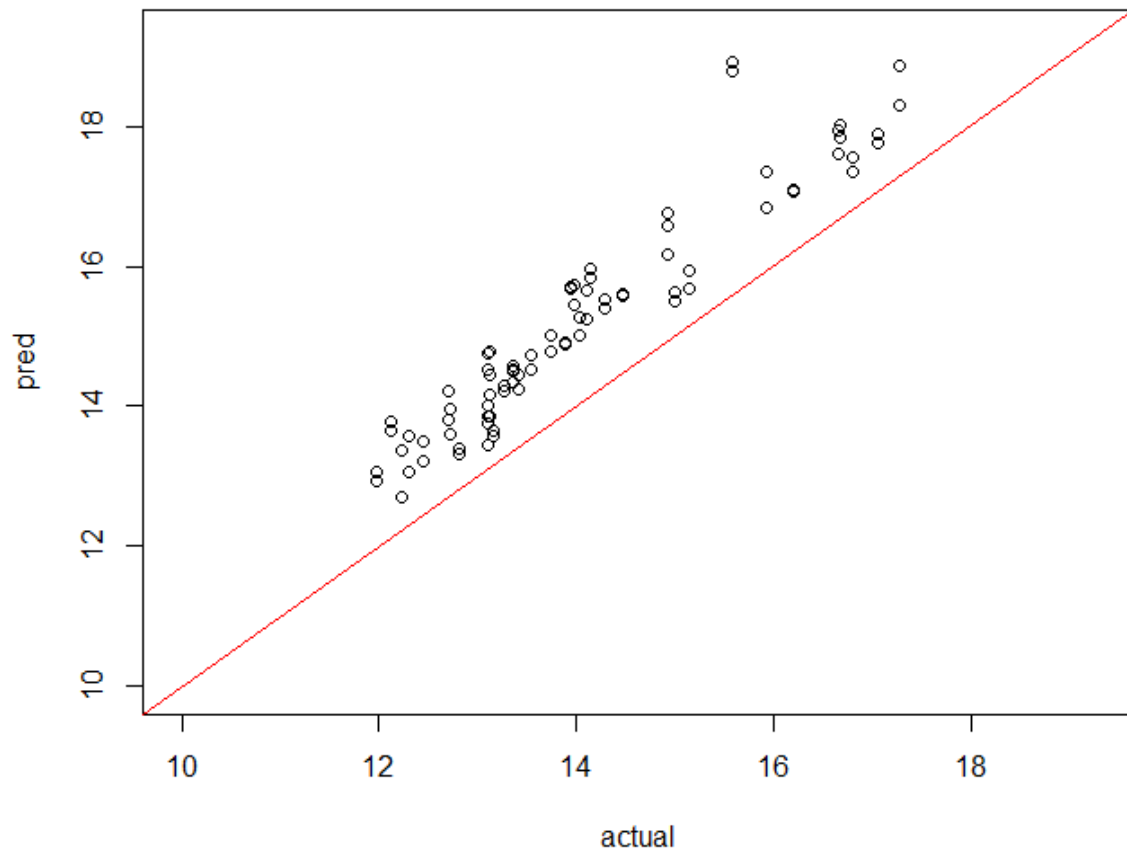
15006 CQU

[1] "Bias: 1.19 R2: 0.91 RMSE: 1.29 SEP: 0.5 Average of population: 14.1 standard Deviation of population: 1.46 Population sample number: 80 and a range of: 11.98-17.28"



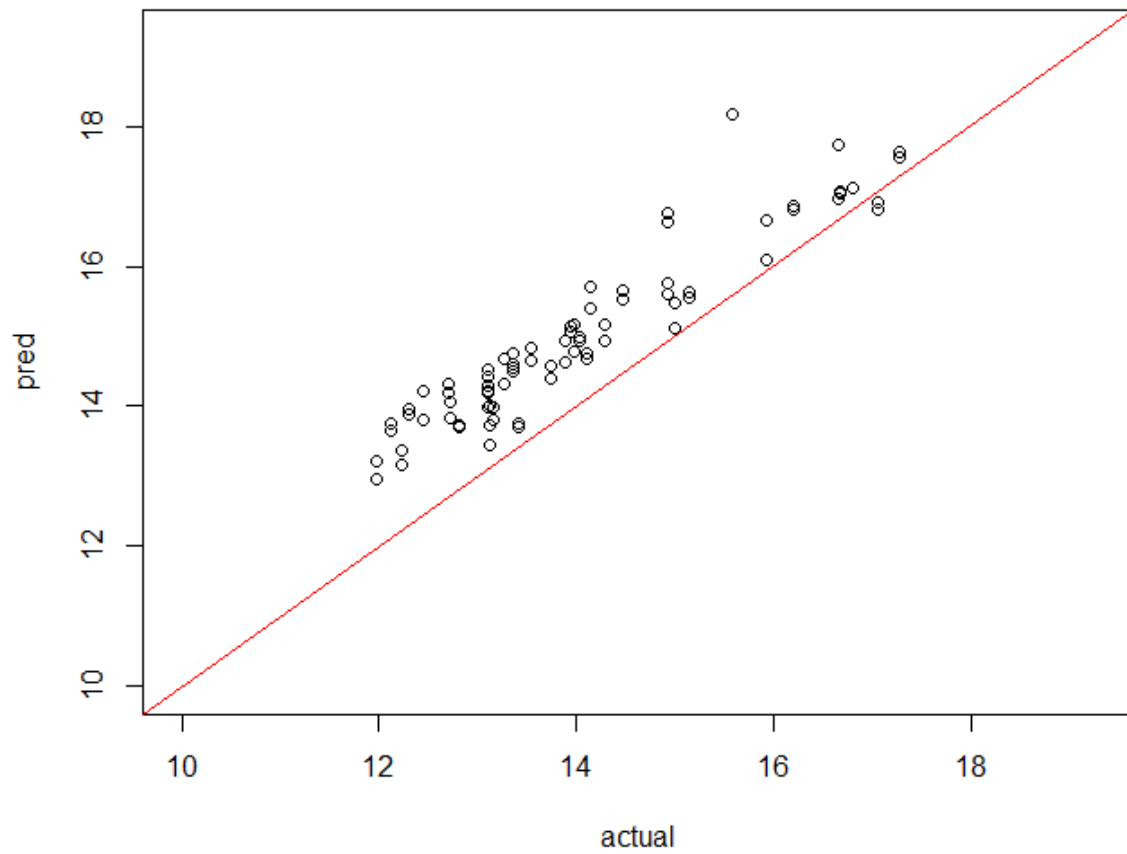
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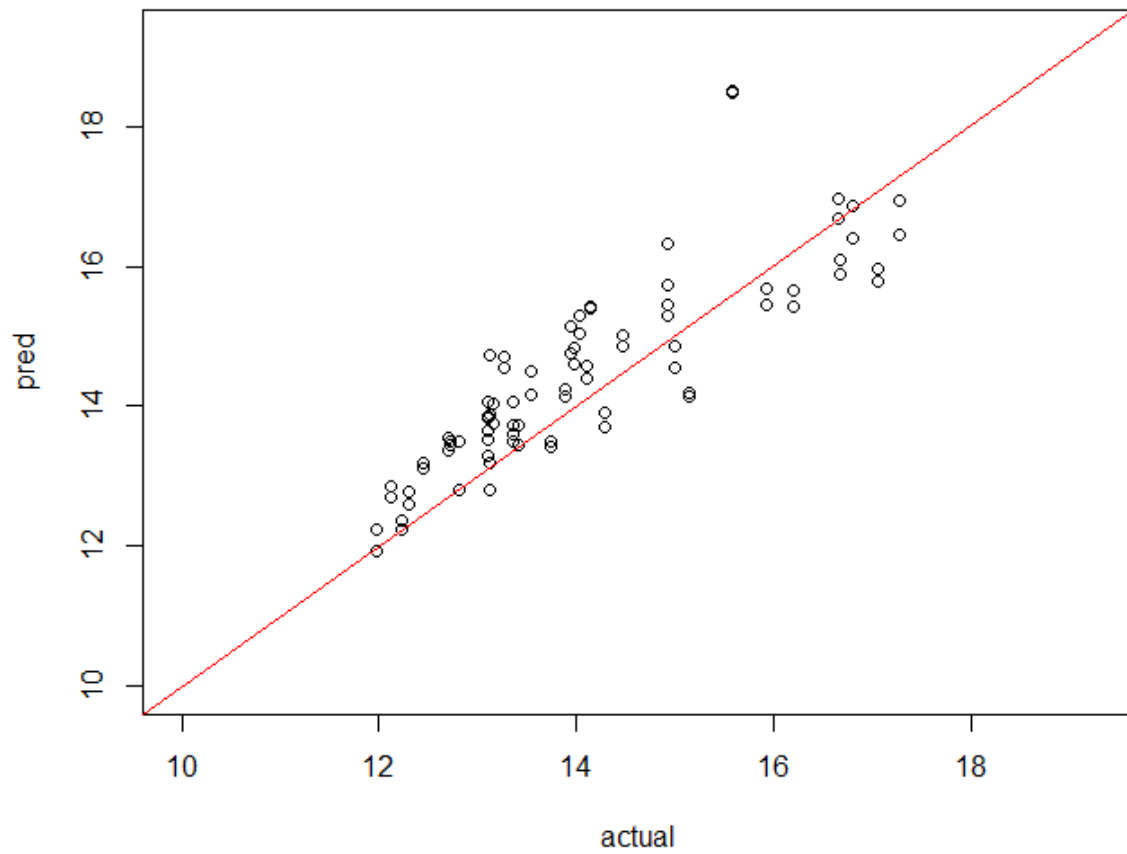
15015 RUDGE

[1] "Bias: 0.96 R2: 0.87 RMSE: 1.09 SEP: 0.52 Average of population: 14.1
Standard Deviation of population: 1.46 Population sample number: 80 and a
range of: 11.98-17.28"



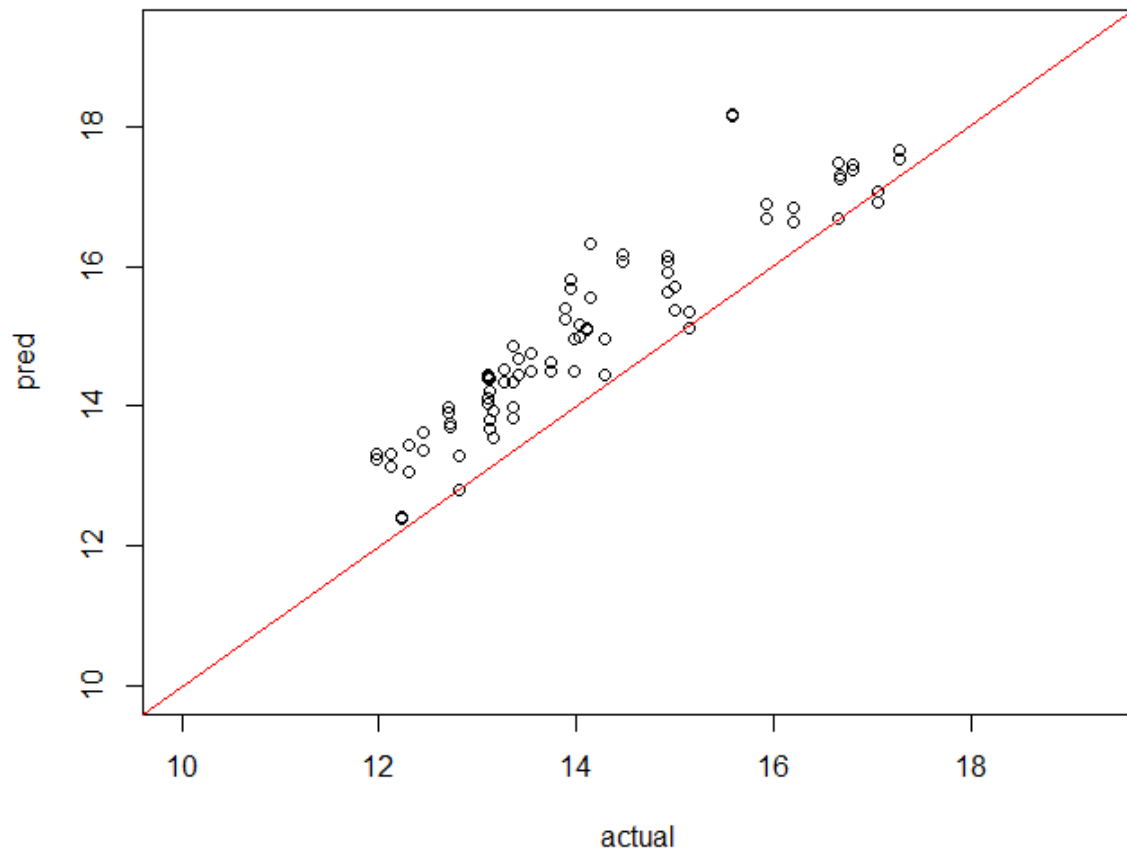
15038 AMIA 8

[1] "Bias: 0.36 R2: 0.74 RMSE: 0.84 SEP: 0.76 Average of population: 14.1
Standard Deviation of population: 1.46 Population sample number: 80 and a
range of: 11.98-17.28"



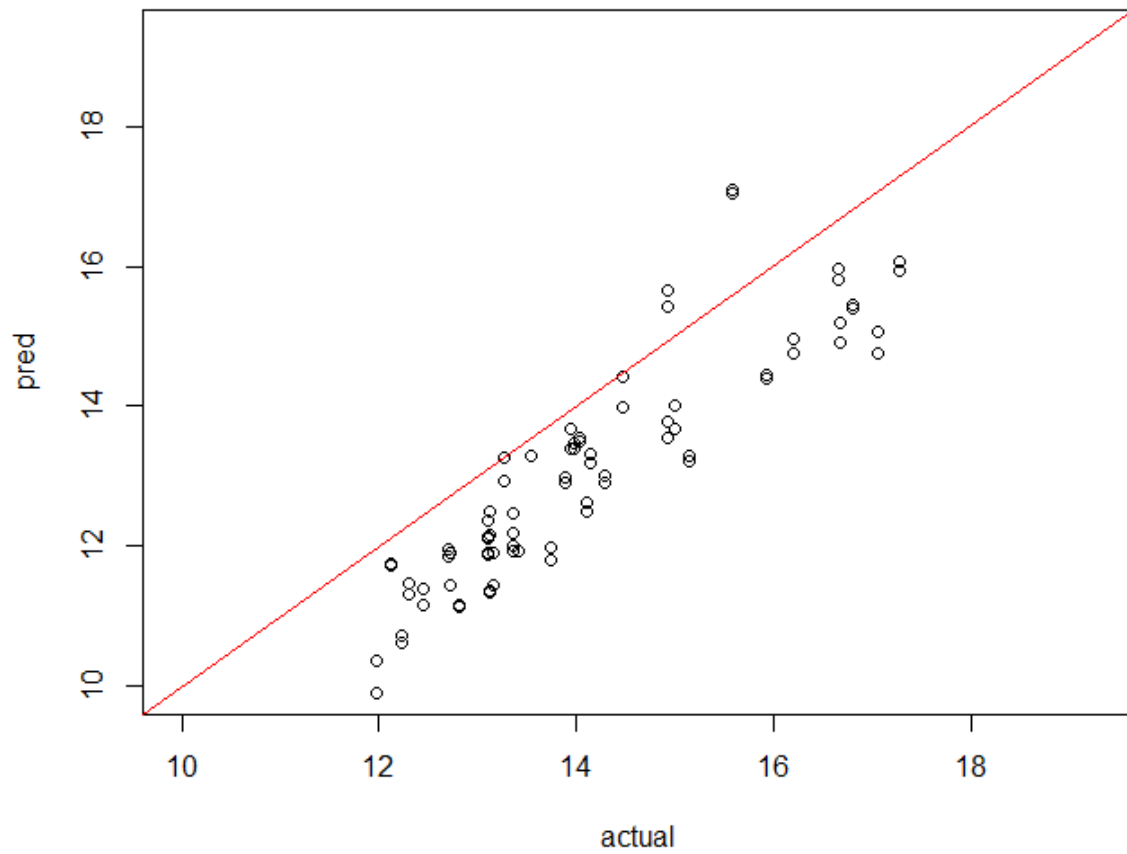
16041 NTFA

[1] "Bias: 0.93 R2: 0.87 RMSE: 1.07 SEP: 0.53 Average of population: 14.1
Standard Deviation of population: 1.46 Population sample number: 80 and a
range of: 11.98-17.28"



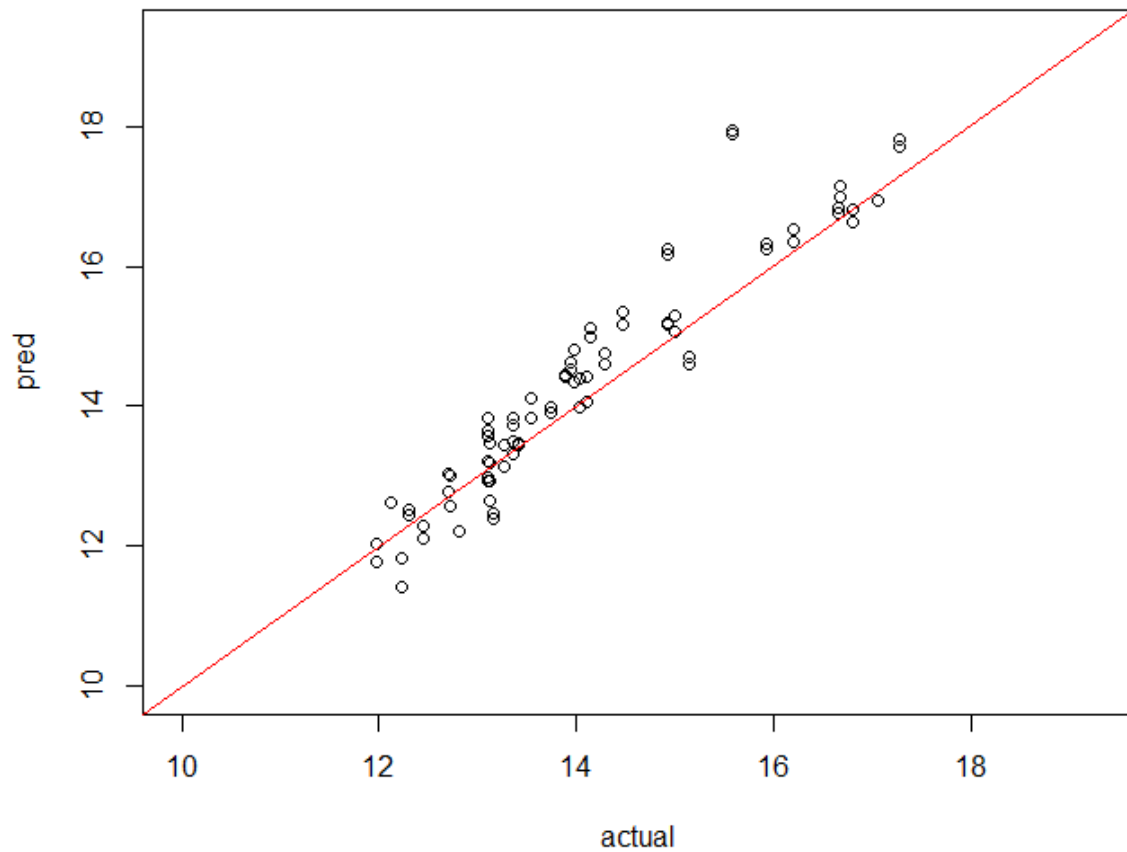
17040 CHAVE

[1] "Bias: -1.03 R2: 0.81 RMSE: 1.25 SEP: 0.7 Average of population: 14.1
Standard Deviation of population: 1.46 Population sample number: 80 and a
range of: 11.98-17.28"



17052 KUNANNARA?

[1] "Bias: 0.24 R2: 0.9 RMSE: 0.59 SEP: 0.54 Average of population: 14.1 standard Deviation of population: 1.46 Population sample number: 80 and a range of: 11.98-17.28"



Appendix A

The below M&E engagement plan outlines how we will engage with our stakeholders. Those stakeholders include:

- Growers/ packers.
- Retailers.
- Wholesalers/Market agents.
- Exporters.
- End customer (consumers).

AMIA will engage with growers on farm, and provide for on farm quality testing using hand held NIR technology (Felix F 750 Produce Quality meter) during the lead up to each regions commencement of harvest and continue the on - farm quality testing for the period from 1 August 2017 to 31 March 2018. Through this engagement AMIA will ensure that growers are fully aware of industry minimum quality standards and ensure growers have access to tools and procedures to assess maturity so that that mangoes are harvested at optimal maturity to align with consumer eating preferences. AMIA will work with all of industry to ensure that quality remains a key driver for growers to ensure improved profitability.

M&E engagement plan

Program logic level	What to monitor	Performance expectations KPIs	How to monitor	Data source (target audience)	When	Responsibility
Activities	<ul style="list-style-type: none">• Grower education of minimum dry matter as published in the 2016 Mango Industry Quality Standards.• Grower education of NIR technology (using the Felix F-750 Produce Quality Meter) and how	<ul style="list-style-type: none">• Include a presentation on quality as part of the preseason roadshow presentations by December 2017.• Conduct at least 100 grower farm visits in the main mango growing regions (Darwin,	<ul style="list-style-type: none">• Record keeping.	<ul style="list-style-type: none">• Growers/ packers.• Retailers• Wholesalers/ Market agents.• Exporters.• End customer (consumers).	<ul style="list-style-type: none">• September 2017 to March 2018.	<ul style="list-style-type: none">• AMIA specific team members will conduct activities.• Conduct calibrations & validations of F750 by CQU / Rudge Produce.

	<p>it relates 'to decision to pick'.</p> <ul style="list-style-type: none"> • Grower in field NIR testing, including pack shed testing where required. • Calibrations and validation of Felix F-750 Produce Quality Meters. 	<p>Katherine, Bowen / Burdekin, Mareeba / Dimbulah and SEQ) by March 2018.</p> <ul style="list-style-type: none"> • Completion of calibration of key varieties (KP, R2E2, Calypso, Honey Gold, Keitt) by March 2018. 				
Outputs	<ul style="list-style-type: none"> • Preseason roadshow presentations. • Monitor fruit quality through grower visits. • AMIA publications <i>My Mango, Mango Matters</i> • Objective Reporting Retailer & Markets. 	<ul style="list-style-type: none"> • Present to at least 200 mango industry stakeholders as part of the preseason roadshows by December 2018. • Conduct at least 100 grower farm visits in the main mango growing regions (Darwin, Katherine, Bowen / Burdekin, Mareeba / Dimbulah and SEQ) and publish a summary of test results in the Final Report by March 2018. • Publish relevant communication relating to dry matter and quality standards in AMIA publications <i>My Mango</i> and <i>Mango Matters</i> 	<ul style="list-style-type: none"> • Record keeping. 	<ul style="list-style-type: none"> • Growers/packers. • Retailers. • Wholesalers/Market agents. • Exporters. • End customer (consumers). 	<ul style="list-style-type: none"> • September 2017 to March 2018. 	<ul style="list-style-type: none"> • AMIA specific team members will report on the activities as part of milestone reports and the final report for this project. • Calibration & validation completed for each F750 machine.

		<p>from September 2017- March 2018.</p> <ul style="list-style-type: none"> # Objective Reporting Retailer/ Markets. 				
Intermediate outcomes	<ul style="list-style-type: none"> Show that NIR technology is a useful tool in the growers 'decision to pick'. Ensure growers have access to tools and procedures to assess maturity so that that mangoes are harvested at optimal maturity to align with consumer eating preferences. Increase the number of positive objective reports. 	<ul style="list-style-type: none"> Conduct an interview with at least one grower from each of the main mango growing regions by March 2018, to find out how they used NIR technology. Show that there has been a percentage increase in sales from 2016/17 season to 2017/18 season. Increase in positive objective reports from last season to this season. 	<ul style="list-style-type: none"> Interviews. Marketing analytics (increased sales). 	<ul style="list-style-type: none"> Growers/ packers. Retailers. Wholesalers/ Market agents. Exporters. 	<ul style="list-style-type: none"> September 2017 to March 2018. 	<ul style="list-style-type: none"> AMIA specific team members will report on activity as part of milestone reports and the final report for this project.
End-of-project outcomes	<ul style="list-style-type: none"> Final report submission: <ul style="list-style-type: none"> - Number of growers adopting new technology (by region). - Data analysed in conjunction to the data collected in MG16002. - Number of samples tested through season. 	<ul style="list-style-type: none"> Felix Produce Quality Meters correctly calibrated for a range of Australian mango varieties. Monitoring of fruit quality (dry matter) on mango orchards/blocks for growers in each key production region. 	<ul style="list-style-type: none"> Calibrations completed. Record keeping analysis. Table of results. 	<ul style="list-style-type: none"> Growers/ packers. Retailers. Wholesalers/ Market agents. Exporters. 	<ul style="list-style-type: none"> September 2017 to March 2018. 	<ul style="list-style-type: none"> AMIA specific team members will report on activity as part of milestone reports and the final report for this project.

	<ul style="list-style-type: none"> - Assessment of Mango Quality in market (from MG15003). - The confirmed R2E2 Dry Matter standard. - Outcomes of Keitt dry matter standard. 	<ul style="list-style-type: none"> • Summary of test results for each region. • Analysis of the project outcomes to demonstrate the extent of uptake of the technology, the impact on the “decision to harvest” and the adoption of evidence based harvest plans and the improved outturn and performance of mangoes in the markets. • Establish a base line of industry participation from which increased adoption of the use of Produce Quality Meters as a measure of fruit quality (dry matter) can be assessed. • A final report will be prepared for industry and a presentation of the project outcomes will be prepared for the post season or preseason 2018 grower meetings. 				
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Appendix 3. MG17002



A. Social media commenting on the NIR produce quality meter in use in field to test mangoes Darwin region, 5 September 2017



B. NIR produce quality meters being used by project staff to measure %DM of harvested fruit during 5 October 2017 in the Katherine region, NT.



C. NIR produce quality meters being used by grower Ben Martin to measure %DM of fruit still developing on the trees 26 October 2017 in the Bowen region.



D. Extract from Courier Mail article commenting on the flavour of mangoes tasting better, 28 October 2017.



E. NIR produce quality meters being calibrated using a selection of KP, R2E2, Calypso and Honey Gold fruit with a range of maturities 17 November 2017 at UCQ Rockhampton, QLD. Selecting fruit for calibration on the day.



F. NIR produce quality meters being used by a grower to measure %DM of harvested fruit 30 November 2017 in the Mareeba region, Queensland.



G. NIR produce quality meters being used by a grower's consultant to measure %DM of harvested fruit 30 November 2017 in the Mareeba region, Queensland.



H. NIR produce quality meters used by project staff to measure %DM of harvested fruit 4 December 2017 in Sydney Produce Markets, NSW during a grower visit and Mess-tival tour.



I. NIR produce quality meters used by project staff Neil Lantzke to measure %DM of harvested fruit 19th February, 2018 Dandaragan, WA during a grower visit.

Appendix 4: Narrative

Date: 13 October 2017

Submitted by: Samantha Frolov

Industry: Mango Industry

Issue: Mango Maturity

Stakeholder: General Manager large international wholesale company, WA.

Engagement: Samantha Frolov received a telephone call from a GM for a large international wholesale and marketing group in Western Australia. The initial conversation was an introduction and brief update about how their business is the ripen & market product for one of WA largest mango growers. The caller asked if he or his team wanted to find more information relating to mangoes to in relation to mangoes would I mind if they contact me. Through the course of the conversation the manager enquired about the use of near infra-red (NIR) technology on farm for Dry Matter testing. He was keen to know if WA growers had access to a F-750 as their company was in support for adoption of the technology.

Reaction: The general manager was very interested in the use of NIR dry matter testing for mangoes that they would be marketing through their wholesale business. He could see the value in the tool being able to assist growers with decision making around picking. Given that his role in the supply chain related to decisions relating to ripening and selling product he recognised the implications of this tool in assisting to maximise his grower's businesses productivity and profitability he also needed to maintain a high standard of fruit quality and therefore mango maturity, at market, within the optimum dry matter range and the importance of how getting the correct ripeness levels for product was.

Actions: AMIA facilitated one initial orchid visit which allowed access to a the NTDPIR machine in the lead up to harvest. WADPIR have invested in a machine with which AMIA orchestrated calibration work for this current season. It will be available to Kununurra growers in the lead up to their harvest 2018/19 season to use in the decision to pick.

This season, Perth markets did not have access to a felix machine to conduct in market testing. The continuum of brix method was the only available method. Next season AMIA aim to have an available machine to replicate the access most other Australian markets have.

Impacts: As only the brix method of determining DM in market in Perth, the delay in brix readings means the results are not available until fruit has potentially be sold to customers. There were some unfavourable brix results during this season.

[illegible]

Appendix 6 MG17002

2018 (this season)					
Region	Farms Visited	Varieties	Period	Visits	Readings
Kununurra	7	KP, R2E2	5/09/2017	7	n/a
Darwin	15	KP, R2E2, Other	29/08/2017-4/10/2017	25	1540
Katherine	6	KP, R2E2, Other	19/09/2017-5/10/2017	8	337
Bowen & Burdekin	25	HG, KP, R2E2,	11/10/2017-28/11/2017	43	3120
Mareeba Region	18	Calypso, HG, KP, R2E2, Other	2/11/2017-4/12/2017	23	2156
Bundaberg & Rockhampton	9	Calypso, HG, KP, R2E2	17/11/2017-10/01/2018	12	965
Northern NSW	1	HG	15/12/2017	1	44
Gin Gin WA	10	KP, R2E2	7/02/2018-19/02/2018	12	174
9 regions	91	Calypso, HG, KP, R2E2, Other	29/08/2017-19/02/2018	131	8336

Table A. Summary of %DM data collected by project staff for MG17002.