HARVEST QUALITY AND STORABILITY OF FIELD PEAS RECEIVED AT AN EXPERIMENTAL 12 TO 13.5% MOISTURE CONTENT BAND

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Division of Entomology

Technical Report No.

Commonwealth Scientific and Industrial Research Organisation

Canberra, Australia

June, 1999

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ISBN No.

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SUMMARY

Field peas (Dun type varieties) were received at South Australian Co-operative Bulk Handling's (SACBH) Wallaroo grain terminal during the 1996/97 and 1997/98 harvests at an experimental 12 to 13.5% moisture content (m.c.) receival limit. The harvest quality of high moisture receivals was compared to field peas received at the current industry limit of up to 12% m.c., and included early and late harvested peas. Seed quality was assessed at outturn following storage in unaerated 'open-topped' concrete cells. 1996/97 seasons peas were stored for 3 and 1997/98 seasons peas for 6 months.

Early harvested peas received into storage were of high quality. Post-harvest breakage was low, seed coat colour was intense, and seed size was large and uniform, compared to late harvested peas. Early harvested peas also had higher germination and lower mould infection levels. There was no marked difference in post-harvest breakage, seed coat colour or germination between early harvested peas received at the experimental moisture content limit and current industry limit of up to 12% m.c. The average seed size of lower moisture content peas however decreased and was less uniform. Late harvested peas (received 4 to 5 weeks later) were smaller and less uniform in size, showed substantial increases in post-harvest breakage and moulding, and had lower germination. The increase in propensity of late delivered peas to split suggests that delays in harvesting influences breakage to a greater degree than lower seed moisture contents. Hard-seededness also became more evident in the late harvested samples.

High moisture peas were stored without any marked deterioration in seed quality for up to 6 months without aeration. Germination was maintained and there was no apparent increase in post-harvest breakage. Seed coat colour of higher moisture content peas from the 1997/98

harvest was shown to darken and brown slightly after 6 months. Although seed colour has less importance in marketing peas for stockfeed, the apparent influence of higher seed moisture contents (relative humidities) on darkening of seed coat colour suggests possible problems with storage of pulses generally.

Moisture had aggregated at the surface of the experimental bulk at 5 months and infection levels of extremely xerophilic *Eurotium* spp. had increased. The data suggests that localised moulding on the surface of undisturbed high moisture pea bulks may result from convection induced moisture migration, and cooling is recommended to disrupt natural convection and inhibit mould growth during long-term storage. Turning bulk peas is not recommended because of the adverse effect on quality that can result from increased breakage of peas due to abrasion and impact during handling.

Isotherm curves that describe the relationship between equilibrium moisture content and water activity (≅equilibrium relative humidity) of whole seeds at 20 and 30°C were determined and show that water activity of dun-type peas stored at 13.5% m.c. (wet basis) is below the critical level of 0.70 required for growth of extremely xerophilic moulds.

A calibration curve of seed moisture contents, comparing levels determined using a standard oven-dried method to levels obtained on-site (at receival) using the Kett Riceter™ meter, showed both under- and over-estimates of moisture using the portable meter and values exceeded +/- 1% m.c. in some instances. Small sample size (4 - 6 seeds) and inherent variability of moisture in freshly-harvested peas are factors likely to have to contributed to the inaccuracy observed at receival.

1. OBJECTIVES

Investigate the effect upon harvest seed quality of receiving Dun type varieties of field peas at a 12 to 13.5% m.c. limit, compared to receiving at the established industry limit of up to 12% m.c.

Assess seed quality of field peas received at a 12 to 13.5% m.c. limit and stored without aeration, compared to receivals at the established industry limit of up to 12% m.c.

Evaluate the performance of the Kett Riceter™ moisture meter (Kett Electric Laboratory, Japan) used to determine moisture contents of Dun type field peas at receival.

Determine moisture isotherms for Dun type field peas at 20 and 30°C.

2. BACKGROUND

Timing of the field pea (*Pisum sativum)* harvest is important to maximise yield and quality. Mature pea crops have inherently poor standing ability. The rambling growth habit and weak stems predisposes mature pea crops to eventually lodge which impairs machine harvesting (Heath & Hebblethwaite, 1985), and the problem is accentuated with the occurrence of wet weather. Australian pea varieties typically produce excessive leaf area and dry matter which compound the problem through smothering and canopy collapse (Armstrong, 1995). Delays in harvesting until the crop reaches established industry moisture receival limits can result in substantial losses in yield and deterioration in seed quality. Current research on genetic improvement (erect growth habit and stronger stems) and improved agronomic practice (early harvesting and use of chemical desiccants) are aimed at improving harvesting efficiency, reducing yield losses.

Yield losses tend to be most severe in late harvested pea crops where the brittleness of the pods accentuates pre-harvest pod drop and, at harvest, pod shattering, cracking and splitting of the seed (Cassells, 1996). Periods of wet and dry weather cause alternate contraction and expansion of the pod and weakening of the pod hinge, resulting in increased pre-harvest shattering and pod drop (Knott, 1985). Weathering of the mature crop can severely reduce seed viability (Powell, 1985), cause discolouration and bleaching of the seed coat and cotyledons (Maguire et al, 1973), and increase mould infection levels (Cassells, unpublished). Dry seed is also considered more susceptible to splitting when threshed (Knott, 1985). Yield losses impinge directly upon the gross margin obtained by the grower and deterioration of the quality of harvested seed can result in down-grading. Commercial storers and processors of pea splits can also incur financial losses through excessive post-harvest breakage and moulding of weathered seed.

The established Australian industry 12% m.c. receival standard for field peas is likely to cause considerable delays in harvesting ripe seed and consequently result in substantial yield and quality losses. The importance of harvesting peas at correct maturity to minimise yield losses is well documented (Heath & Hebblethwaite, 1985; Knott, 1985). A previous study by the Stored Grain Research Laboratory (Cassells, 1996), showed the optimum time for machine harvesting of blue (var. Jupiter) and white (var. Bohatyr) type field peas was when seed dried to a moisture content of 15%. During a rain affected harvest, a 15 day delay resulted in a 24% loss in yield of the field pea variety Bohatyr as seed was left to dry "on-head" from 15.5 to 13.8% m.c.

The quality of field peas stored for prolonged periods needs to be maintained, especially where early harvesting of crops has resulted in the receival of premium quality seed. Safe storage of pulses depends largely upon the condition of the seed at harvest (degree of weathering, grain moisture content and temperature), storage temperature, length of storage, and storage construction. Results from previous laboratory studies conducted by SGRL (Cassells, 1996) show that premium quality field peas (var. Jupiter and Bohatyr) can be safely stored under controlled conditions at 20°C for 3 and 10 months at 14.5% and 13.5% m.c. respectively and at 27°C for 3 and 10 months at 13.5% and 12.5% m.c. respectively. Short-term (3 months) storage at 15% m.c. was shown to be unsafe and cooling or drying of the seed would be required to minimise deterioration.

To evaluate seed quality and handling advantages of receival and storage of field peas at moisture contents between 12 to 13.5%, field trials were conducted by SACBH at the Wallaroo grain terminal during 1996/97 and 1997/98 seasons. Post-harvest quality and storability of field peas received at the higher moisture content limit were compared to deliveries received at the current industry limit of up to 12% m.c. Any change in the industry moisture content receival standard for peas must be consistent with storability and marketability. Data from these field trials, and continued evaluation of a higher 13.5% m.c. limit by SACBH, provide a practicable basis for consideration of increasing the industry limit.

3. MATERIALS AND METHODS

3.1 Harvest and storage sampling

Growers were advised by SACBH prior to harvest of the establishment of an experimental 12 to 13.5% m.c. limit at Wallaroo grain terminal to accommodate receival of early harvested peas. Samples were collected for quality analysis from all truck loads received within the 12 to 13.5% m.c. band. A representative number of samples were taken of field peas received at the same time at moisture contents up to 12%. During the 1997/98 harvest, samples were also taken from truck loads received 4 to 5 weeks after the initial (early) sampling period at moisture contents up to 12%.

During storage, samples of 1997/98 seasons peas were taken from the surface region of the experimental bulk at 5 months post-harvest. A cross-transect was used to obtain a representative profile of seed moisture in the upper region of the bulk. Samples were taken from the surface, and at depths of 1 m and 2 m using a spear fitted with a collection chamber. Selected pea samples were also assessed for mould infection levels.

On outturn, a running composite sample was taken from both the experimental and control (up to 12% m.c.) pea bulks for subsequent quality analysis.

3.2 Quality assessment

Grain moisture content : Moisture content was determined in the laboratory using the standard ISO oven-dried method (Anon., 1985). Samples had been allowed to equilibrate for 2-3 weeks at 4°C in sealed containers prior to moisture determination. Results for receival samples were compared to measurements obtained at the terminal using the Kett Riceter™ grain meter. Approximately 50 g of seed was taken from each truck load composite, ground in a coffee-type grinder, and a sub-sample of the meal taken for moisture determination. The portable meter was set on the calibration scale and values converted to % moisture content using the Riceter™ field pea conversion table.

Breakability : 100 g of unbroken sample was processed in a Steinlite™ (Model CK2-M) Maize Breakage Tester for 4 minutes. The sample was sieved to remove all broken seeds. Percentage breakability was calculated from the weight of broken seed, compared to total weight of the sample.

Colour : Colour of the whole seed was measured using a Minolta™ Croma Meter with a CR-310 (50 mm diameter) measuring head. Readings were taken using the Commission Internationale l'Eclairage L*a*b* system. L* quantifies brightness, dark to light (0 to 100); a* redness (-ve green to +ve red); and b* yellowness (-ve blue to +ve yellow) (Hunter and Harold, 1987).

Seed size and screenings : 200-350 g of peas were used to determine seed size for inloading samples and 500 g to determine seed size and screenings of outturn samples. Seed size was determined by sieving the sample through 7 and 6 mm diameter round aperture sieves on a Seedburo™ Model P shaker. Screenings were ascertained by sieving the sample through a slotted (11/64" x 3/4") sieve. The mechanical shaker was operated on 100 cycles for each determination.

Germination : Germination percentage was assessed using the International Seed Testing Association Rules (Anon., 1993). 200 seeds per sample were germinated between moistened sheets of paper at 20°C under artificial light for 8 days. Hard seeds were left for a further 5 days on moistened paper and then assessed for germination.

Mycology : Mould assessments were conducted by the Sydney Laboratory of Food Science Australia. Direct and dilution plating on DRBC agar were used for total yeast and mould counts, and DG18 agar was used specifically for the detection of xerophilic fungi such as *Eurotium* spp. Direct plating results are expressed as % of seed infected and dilution plating results as colony forming units (cfu) per gram of sample.

Moisture isotherms: Approximately 400 g of seed was placed into sealed glass vessels and maintained for one week at 20 or 30°C in a controlled temperature water bath to enable equilibration prior to testing. Relative humidity of the field peas was determined in a closed loop situation using a MBW Model DP 3-D dewpoint meter (MBW Elektronik AG, Wettingen, Switzerland). The moisture content was determined using the ISO oven-dried method (Anon., 1985) and results are reported as "wet basis". Results were fitted using the modified Chung-Pfost equation (Sun and Woods, 1993) providing moisture desorption isotherms for water activity versus moisture content. Water activity (a_w) is numerically equivalent to equilibrium relative humidity of the seedlot, where a_w = erh/100.

4. RESULTS AND DISCUSSION

4.1 Receival tonnage and moisture content

Dry weather during the 1996/97 harvest resulted in only 454 t of high moisture content field peas being received at Wallaroo grain terminal. The average moisture content (determined using oven-dried method) of peas received at the experimental limit was 11.8%, ranging from 10.3 to 13.2% (Table 1). Field peas received at the same time up to 12% m.c. had an average moisture content of 10.6%. The high moisture content field peas were transferred post-harvest from a 2000 t to 500 t cell and held in unaerated storage for a 3 month period.

Frequent rainfall during the 1997/98 harvest and a favourable response by growers to requests to harvest field pea crops earlier, resulted in 2,586 t of peas being received in the experimental 12 to 13.5% m.c. band. The average receival moisture content was higher than the previous season at 12.4%, ranging from 11.1 to 13.9%. Field peas received at the same time up to 12% m.c. had an average moisture content of 10.6%. Deliveries received one month later had a lower average moisture content of 8.6%. A 2,000 t cell filled to capacity with high moisture field peas was used as the experimental bulk and the peas were subsequently stored unaerated for 6 months. The early harvested peas received up to 12% m.c. were held under similar conditions. However, late harvested, drier peas were apparently used to complete filling of the 'control' cell (which is reflected in quality assessment of outturned samples).

4.2 Moisture content during storage and at outturn

At 5 months post-harvest, moisture determination of 1997/98 seasons peas in the upper 2 m of the experimental bulk showed some moisture aggregation at the surface (Table 2). The highest moisture content (16.6%) occurred at the peak. Moisture levels were lower at 1 and 2 m depth, with an average level of 12.3 and 12.2% respectively.

Moisture migration is a problem in undisturbed, unaerated grain bulks, and can result in moulding and crusting at the extremities (surface and grain adjacent to walls). Griffith (1964) demonstrated that, under Australian conditions, a high initial grain temperature had a greater influence than initial moisture content on the possible occurrence of moisture damage at the

surface of undisturbed, unaerated cereal bulks. The formation of steep temperature gradients in warm grain bulks in response to cool ambient conditions was shown by Griffith to be a precursor for convection induced moisture movement. In this study, there was no visual evidence of moisture damage or heavy moulding of peas at the bulk surface at the time of inspection. Management of moisture migration by turning and/or transfer of peas between stores to mix wetter seed at the surface with the rest of the bulk is difficult because of the adverse effect on quality that can result from increased breakage of peas due to abrasion and impact during handling. The use of aeration to disrupt the formation of convection currents and cool seed is a preferred option and may be required when higher moisture content peas are stored for long periods.

There was no evidence of moisture loss from the high moisture pea bulk during storage. At outturn, the average moisture contents of 1996/97 and 1997/98 seasons peas were the same as the inloading average (Table 1). The reduced variance in measured moisture levels recorded at outturn indicates substantial equilibration of moisture contents between individual loads had occurred. The average moisture content of peas sampled from the control cell at outturn was lower compared to early harvested peas received at up to 12% m.c., suggesting that a large proportion of truck loads received into the control cell occurred later in the harvest period.

4.3 Post-harvest breakage

High and low moisture content field peas collected at the same sampling time exhibited similar levels of post-harvest breakage (Table 1). Field peas collected later during the 1997/98 harvest showed a three-fold increase in breakage, suggesting that delays in harvesting influences breakage to a greater degree than a lower seed moisture content. Post-harvest breakage of high moisture field peas showed no change with storage time. Outturn breakage of drier and late harvested deliveries during season 1997/98 appeared to have increased during storage. However, comparison of breakage values between inloading and outturned peas received up to 12% m.c. was difficult because of the uncertainty of the origin of peas held in the control cell.

4.4 Seed size and screenings content

Seed was less uniform and substantially smaller in size for drier, late harvested peas (Table 1). The ratio of different seed sizes (as % of total sample) was similar for the inloaded and outturned peas received in the 12-13.5% m.c. band. Equilibration of seed moisture within the bulk during storage reduced the variation in seed size observed in freshly harvested samples.

The average screenings content in outturned low moisture content peas was 11.1%, compared to high moisture peas at 4.6%. Screenings comprised broken and split seed, and grain dust. The lower screenings level in high moisture peas would be expected to reduce the dustiness of seed during handling, and this was supported by observations recorded by SACBH staff following outturn of 1996/97 seasons peas.

4.5 Colour of seed coat

The green hue and uniformity of colour was similar between early harvested, high moisture content peas and drier peas received at the same time (Table 1). There was minimal change in colour following 3 months storage of field peas from the 1996/97 harvest. Seed coat colour of 1997/98 seasons high moisture peas darkened following 6 months storage; the colour changing to predominantly reddish-brown, as indicated by an increase in *a* value. In comparison, drier peas tended to retain seed coat colour. The smaller seed size of late harvested, drier peas, increased the intensity of green and brown hued seeds.

The retention of uniform seed colour is important in determining the marketability and value of field peas destined for human consumption. Although Dun-type varieties are generally exported as stockfeed, discolouration due to weathering and subsequent darkening of the seed coat during storage, has implications for pulses exported for human consumption. A previous study (Cassells, 1996) showed that ‘blue’ type pea varieties needed to be stored at 20°C to maintain the strong green colour over 12 months.

4.6 Germination

The germination of early harvested field peas was substantially higher than late harvested seed (Table 3). Lower germination of late harvested, weathered seed, indicates substantial ageing and loss of quality occurred prior to storage. Seed viability provides a direct indication of ageing and condition of the seed. The rate of loss of seed viability is a consequence of cytological, physiological and chemical changes that occur as seeds progress through various

stages of deterioration during storage, resulting in seed death when conditions are sufficiently severe (Roberts 1973a, 1973b). McGuire *et al* (1973) showed that there is a strong association between loss of viability and vigour to the degree of bleaching in pea seeds.

The data show that loss of germination during storage was not substantial for either early or late harvested peas. Despite the weathered condition of late harvested peas, their low moisture content apparently minimised loss of germination. Seed ageing is a function, not only of time, but also of temperature and moisture (Ellis & Roberts, 1981). Moisture content has a predominant influence upon the longevity of seeds and previous studies with field peas and lupins (Cassells, 1996) and chickpeas (Cassells, unpublished) show weathered seed can be safely stored for up to 12 months at low moisture contents (<10%, w.b.).

The percentage of hard seeds present increased in response to lower moisture contents and delays in harvest. Hard-seededness decreased with time in storage.

4.7 Field and storage moulds

Mould infection levels detected on field peas collected during the 1996/97 harvest were generally low (cfu = 10^2 to 10^3), although the level and diversity of species tended to increase on "wetter" samples (Figure 1). During storage, the level and diversity of the moulds on the field peas declined after 3 months (cfu = 10^1 to 10^2) (Figure 2), indicating conditions were unfavourable for mould growth. Infection levels of field type fungi on low moisture, late harvested peas collected during the 1997/98 harvest were greater (cfu = 10^4) compared to earlier harvested, high moisture seed (cfu = 10^3) (Figure 3), with *Alternaria* and *Penicillium* the predominant species present.

Peas taken from the undisturbed bulk surface after 5 months storage showed a relatively high level of mould infection (cfu = 10^4 to 10^5)(Figure 4). *Eurotium* spp. were the predominant storage fungi present, with low levels of *Aspergillus* and *Penicillium* spp. also detected. *Eurotium* spp. grow at water activities (a_w) as low as 0.70 and *Aspergillus* spp. at 0.75-0.78 (Pitt & Hocking, 1997). Seed moisture contents at the surface indicated that water activity exceeded 0.70, as calculated from an isotherm at 20°C (Figure 7a). This combined with high ambient temperatures at the top of the cell during the warmer months would favour the growth of moulds. There was however no visual evidence of heavy moulding observed during

sampling of higher moisture content peas. The low levels of *Aspergillus* and *Penicillium* spp. present thoughout the rest of the high moisture pea bulk also indicated that conditions remained marginal for the growth of xerophilic fungi during storage.

The moisture contents of peas outturned from the experimental cell were generally well below the threshold moisture levels required for growth of the most tolerant xerophilic fungi present and this was reflected by low levels of infection (cfu = 10^2). The high level of fungi previously detected at the bulk surface were present in samples 6 and 7 (Figure 5). The characteristic funnel flow of grain from vertical cells does present a potential problem when moulded grain present at the surface of undisturbed bulks is outturned as individual truck loads, particularly when grain conditions have favoured the growth of toxin producing fungi. In this study, the water activity of peas at the surface remained well below the minimum level required for growth of toxin producing fungi such as *Aspergillus flavus* (min. a_w = 0.82 @ 25°C and 0.81 @ 30°C; Pitt & Miscamble, 1995). Infection of *A. flavus* on stored peas and the production of aflatoxins can occur in circumstances of poor storage. Aflatoxins have been reported in tropical and sub-tropical zones in various types of pulses owing to post-harvest damage, but much less frequently than in cereal grains (Webley *et al*, 1997). Mills & Woods (1984) recorded *A. flavus* in farm stored peas in Canada, although no aflatoxins were detected.

4.8 Calibration of Kett Riceter™ moisture meter to standard oven-dried method

A calibration curve, comparing the moisture content determined at receival using the Kett Riceter™ moisture meter to determinations using a standardised oven-dried method for both the 1996/97 and 1997/98 seasons, is given in Figure 6. The relatively large size of field peas and variation in moisture content between seeds are factors likely to have contributed to the variance observed in readings obtained using the Kett Riceter™ meter. Electrical conductivity of the seed is also known to be affected by weathering and differences in temperature between the substrate and sampling environment (Stenning & Channa, 1987). Although temperature is compensated to a degree in contemporary electrical conductivity type moisture meters, large differences between substrate and sampling environment (e.g. air-conditioned rooms) frequently occur. The average difference in moisture content of all samples determined using the Kett Riceter™ moisture meter, compared to the standard oven method, was +0.7% (1996/97) and +0.4% (1997/98) for high moisture field peas, and +0.3% (1996/97 and 1997/98) for low moisture peas.

4.9 Moisture isotherms

Moisture desorption isotherms for Dun type field peas from the 1997/98 harvest determined at 20 and 30°C are given in Figure 7a. An isotherm combining data from 1996/97 and 1997/98 harvests at 20°C is given in Figure 7b. Importantly, moisture isotherms provide a useful management tool that can be used to establish safe storage conditions for field peas based on knowledge of the water activity (≅ e.r.h.) that is critical for the growth of moulds at favourable temperatures. At 20°C, Dun type peas at 13.5% m.c. have an equivalent water activity (a_w) of 0.63, and at 30°C, an equivalent a_w of 0.67. Both these values are below the critical a_w of 0.70 required for the growth of extremely xerophilic (storage) moulds.

5. CONCLUSIONS

Quality of early harvested peas received at the experimental (12-13.5%) and control (<12%) moisture content limits did not differ substantially in post-harvest breakage, seed coat colour, germination, or mould infection levels. The average seed size of lower moisture content peas however decreased and was less uniform. Drier, late harvested peas (received 4-5 weeks later) showed substantial decreases in seed size and germination, and increases in post-harvest breakage and moulding. The increase in propensity of late delivered peas to split suggests that delays in harvesting influences breakage to a greater degree than lower seed moisture contents.

There was no marked deterioration in seed quality of field peas received at the experimental moisture content limit (12-13.5%) following 6 months storage without aeration. The data show no increase in post-harvest breakage or loss in germination. Seed coat colour of higher moisture peas darkened and browned slightly with storage, and this factor may need to be considered when stored peas are destined for human consumption markets. Breakage of low moisture content field peas appeared to have increased on outturn, but there was uncertainty associated with the origin of the seed held in the control cell.

Eurotium spp. developed in localised regions at the bulk surface where moisture had aggregated following 5 months storage. The low levels of *Aspergillus* and *Penicillium* spp. present on high moisture peas indicated that conditions remained marginal for the growth of xerophilic fungi during storage. Long-term storage of high moisture field peas may require active cooling to minimise aggregation of moisture and consequent moulding at extremities of the bulk.

Data from 1996/97 and 1997/98 harvests show that moisture measurements of field peas within the range 9-14% using the Kett Riceter™ meter deviate substantially from the actual moisture content. However, values showed both positive and negative differences and overall the average moisture content obtained using the Riceter™ meter was 0.4% above the level determined using a standard oven-dried method.

Moisture isotherms obtained at 20 and 30°C enable the relationship between seed moisture content and equilibrium relative humidity to be established at those temperatures and provide a useful management tool for predicting storage conditions that inhibit mould growth.

6. ACKNOWLEDGMENTS

Our thanks are extended to Head Office and Regional Staff of South Australian Co-operative Bulk Handling Limited for their valuable assistance, particularly Geoff Masters, Reid Toogood, Stephen Annells, and the staff at the Wallaroo Grain Terminal.
Thanks are also extended to Jane Green for expert technical support, to Dr Ailsa Hocking and Nick Charley for mycological analysis and technical advice, and the partners of the Stored Grain Research Laboratory for financial assistance to undertake this study.

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Table 1. Quality assessment of Dun type field peas received at Wallaroo grain terminal during the 1996/97 and 1997/98 seasons.
Variance given in parenthesis.

Harvest season	Moisture content receival limits (%, w.b.)	Inloading / outturn	Moisture content (%, w.b.)	Breakability (post-harvest) (%)	Seed size (%) Screen aperture (mm) 7	6	<6	Colour L*	a*	b*
1996/97	12-13.5	inloading	11.8 (0.71)	0.5 (0.19)				48.3	1.0	17.8
		outturn	11.8 (0.15)	0.6 (0.07)				47.9	1.4	17.9
	<12	inloading	10.6 (0.69)	0.5 (0.39)				49.2	0.4	17.5
		outturn	9.6 (0.06)	0.7 (0.08)				48.7	1.2	16.8
1997/98	12-13.5	inloading	12.4 (0.39)	0.9 (0.33)	45.6 (478.5)	44.0 (243.6)	10.4 (58.0)	49.3	1.6	19.2
		outturn	12.4 (0.08)	1.1 (0.27)	43.4 (73.5)	44.7 (17.8)	11.9 (23.9)	48.4	3.7	17.7
	<12	inloading	10.9 (0.38)	1.1 (0.68)	32.8 (374.1)	47.8 (101.1)	19.5 (180.4)	50.0	1.2	19.2
	<12 late receivals	inloading	8.6 (0.95)	3.1 (3.26)	12.9 (238.2)	50.8 (110.3)	36.3 (340.4)	47.6	0.9	17.9
	<12 including late receivals	outturn	8.8 (0.20)	6.2 (5.79)	21.3 (36.0)	55.7 (11.4)	23.0 (24.9)	50.0	1.2	16.7

Table 2. Moisture contents of field peas samples collected from test cell at Wallaroo grain terminal on 07/05/98.

Sample points shown on diagram 1. 1 - 17 surface samples.
1A - 17A sampled @ 1 m depth. 1B - 17B sampled @ 2 m depth.

Sample number	Grain moisture content (%)	Sample number	Grain moisture content (%)	Sample number	Grain moisture content (%)
Surface		**1 m Depth**		**2 m Depth**	
1	16.6	1A	12.5	1B	12.4
2	14.8	2A	12.3	2B	12.3
3	15.1	3A	12.4	3B	12.3
4	15.9	4A	12.4	4B	N/A
5	15.6	5A	12.5	5B	12.4
6	14.8	6A	12.4	6B	12.6
7	14.7	7A	12.3	7B	N/A
8	15.1	8A	12.4	8B	12.3
9	14.6	9A	N/A	9B	N/A
10	11.6	10A	12.2	10B	11.8
11	11.6	11A	12.1	11B	12.0
12	11.4	12A	12.0	12B	11.9
13	12.1	13A	12.2	13B	12.1
14	12.4	14A	12.3	14B	12.4
15	13.6	15A	12.5	15B	12.2
16	13.9	16A	12.4	16B	12.1
17	12.1	17A	12.1	17B	N/A
Average	**13.9**		**12.3**		**12.2**

Diagram 1

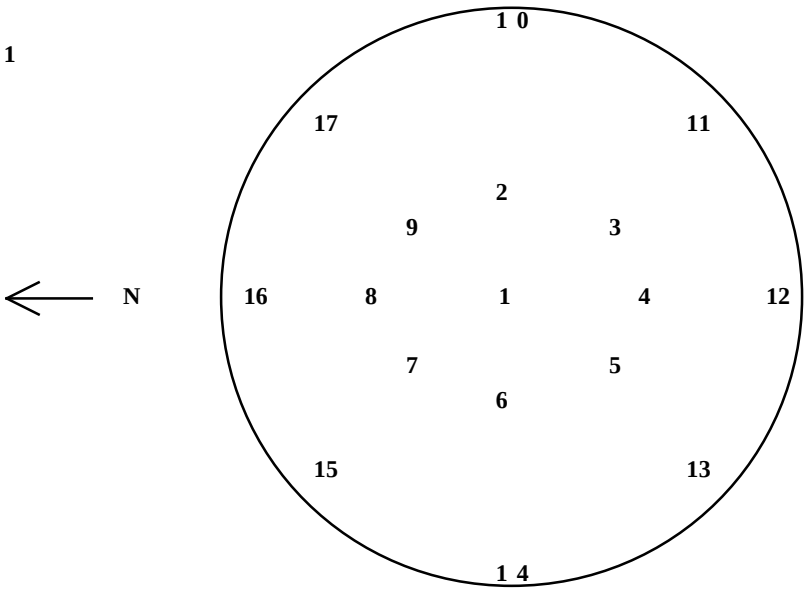


Table 3. Germination assessment of Dun type field peas received at Wallaroo grain terminal during the 1996/97 and 1997/98 seasons.

(a) Hard-seeds present in sub-sample, expressed as % of total.

(b) Hard-seeds that germinated after an additional 5 day germination period, expressed as % of total.

Harvest season	Moisture content receival limits (%, w.b.)	Inloading / outturn	Hard seeds (%) (a)	Germinated hard seeds (%) (b)	Total germination (%)
1996/97	12-13.5	inloading	1.8	1.0	97
		outturn	0.2	0.3	95
	<12	inloading	9.0	5.0	93
		outturn	6.7	3.7	92
1997/98	12-13.5	inloading	1.2	0.9	96
		outturn	0.3	0.3	94
	<12	inloading	5.5	2.5	94
	<12 late receivals	inloading	16.6	5.2	79
	<12 including late receivals	outturn	12.7	4.5	83

Figure 1. Mould infection levels on inloading high moisture field peas received at the Wallaroo grain terminal

during the 1996/97 harvest.

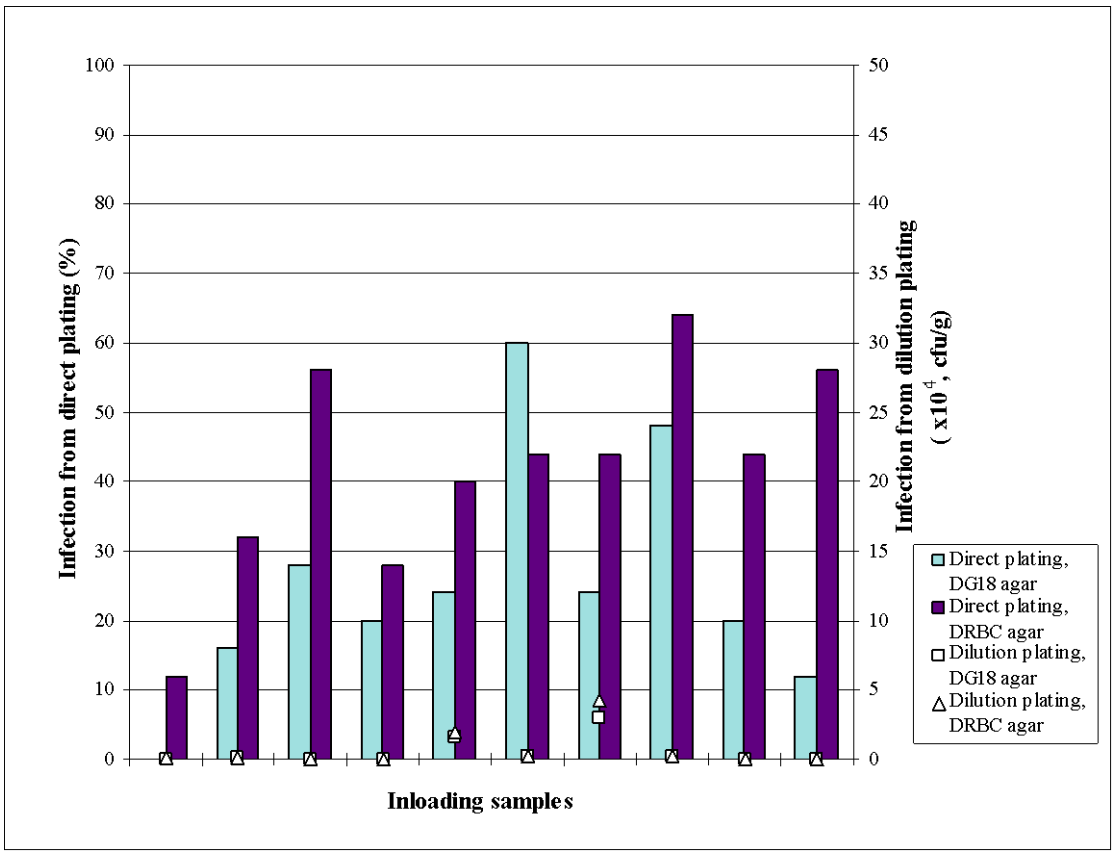


Figure 2. Mould infection levels on high moisture field peas outturned at the Wallaroo grain terminal during the1996/97 harvest.

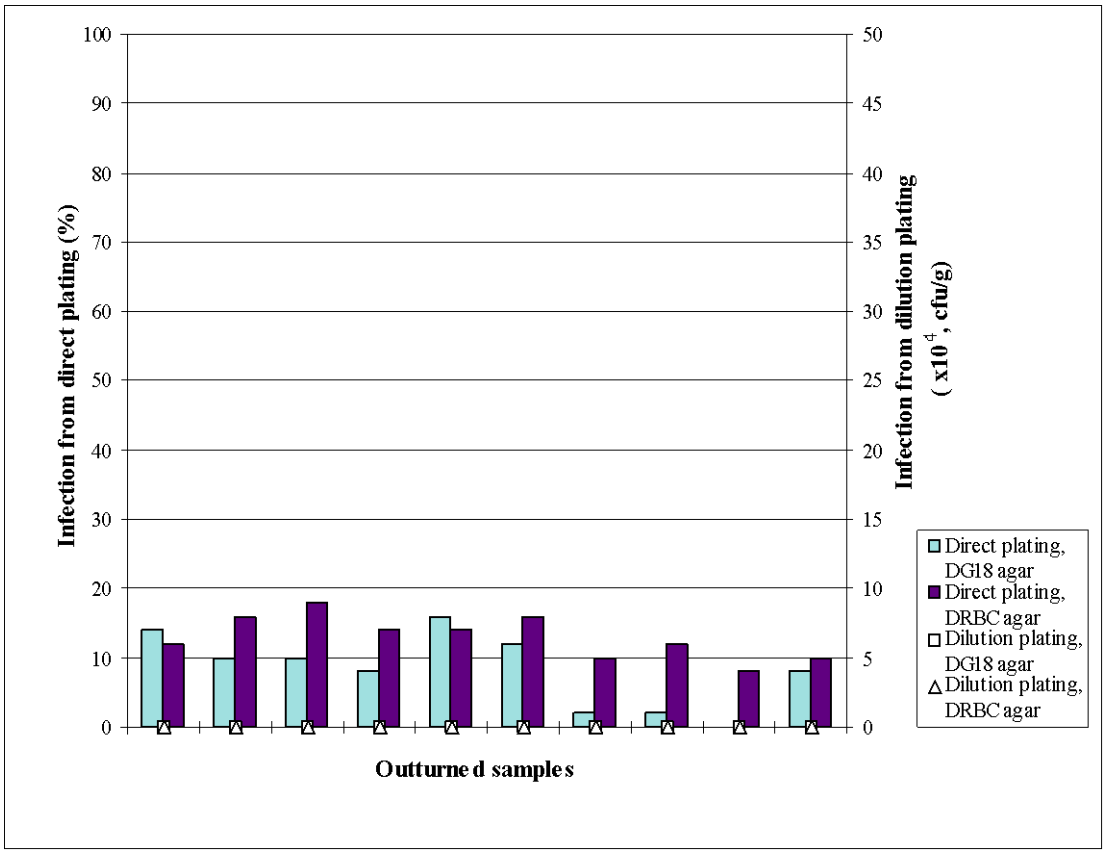

Infection from direct plating (%)
Infection from dilution plating
(x10 4 , cfu/g)
Outturned samples
Direct plating, DG18 agar
Direct plating, DRBC agar
Dilution plating, DG18 agar
Dilution plating, DRBC agar

Figure 3. Mould infection levels on inloading early and late harvest field peas received at the Wallaroo grain terminal during the1997/98 harvest.

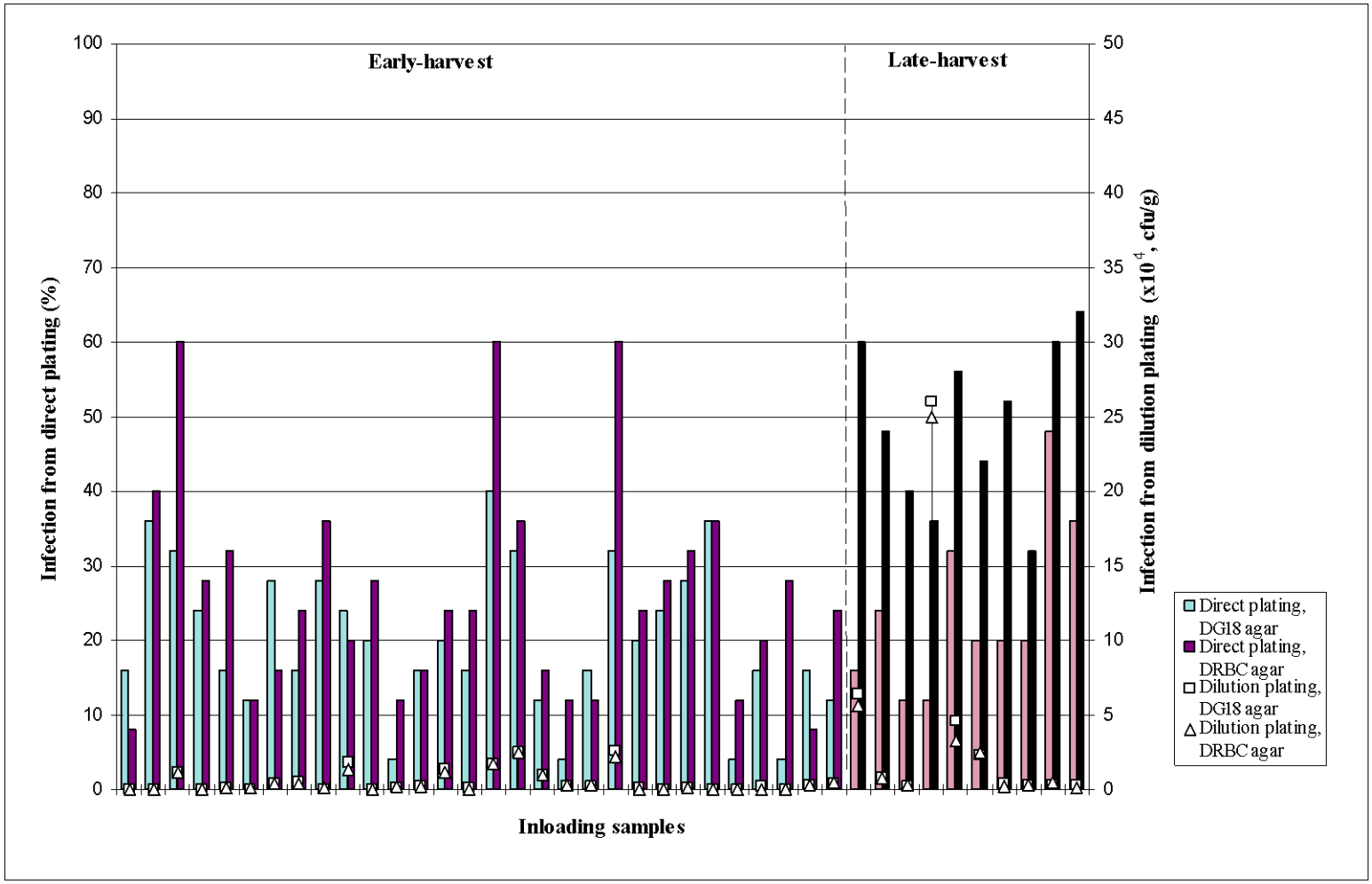


Figure 4. Mould infection levels on high moisture field peas collected from the bulk surface at 5 months post-harvest (7/5/98) .

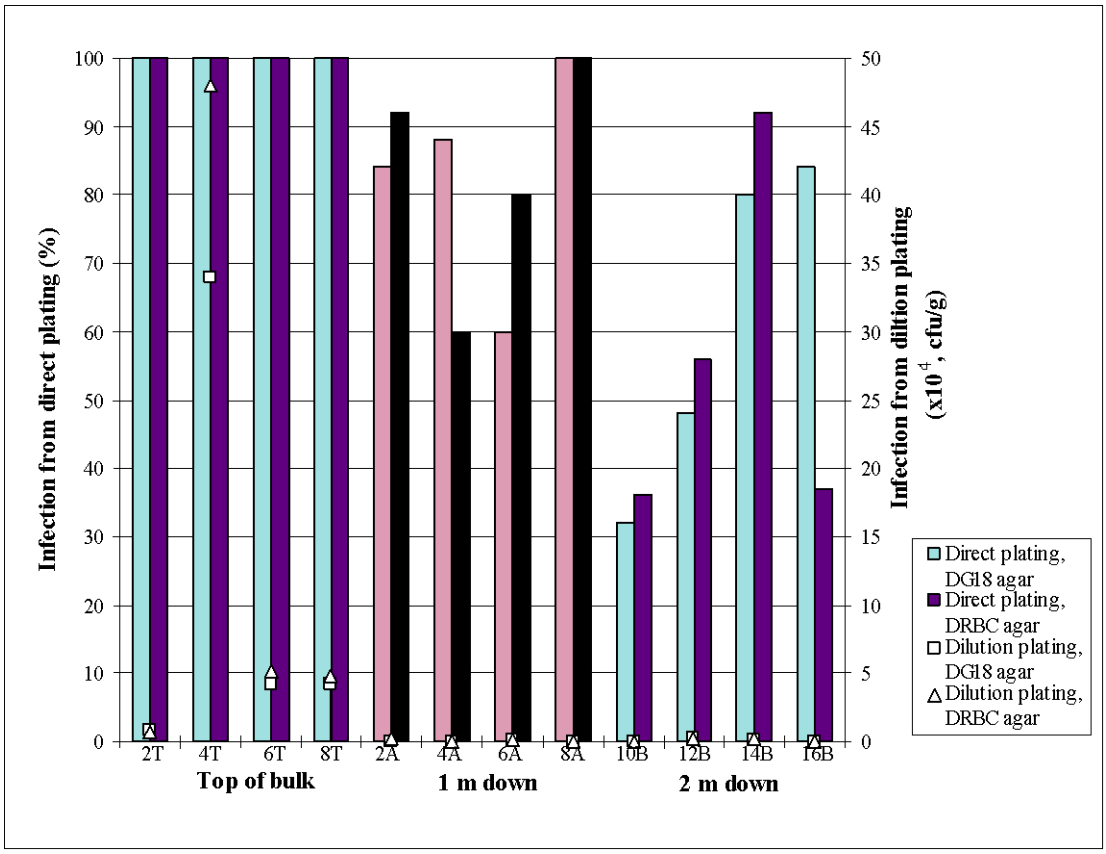


Figure 5. Mould infection levels on high moisture field peas outturned from the Wallaroo

grain terminal 27/5/98.

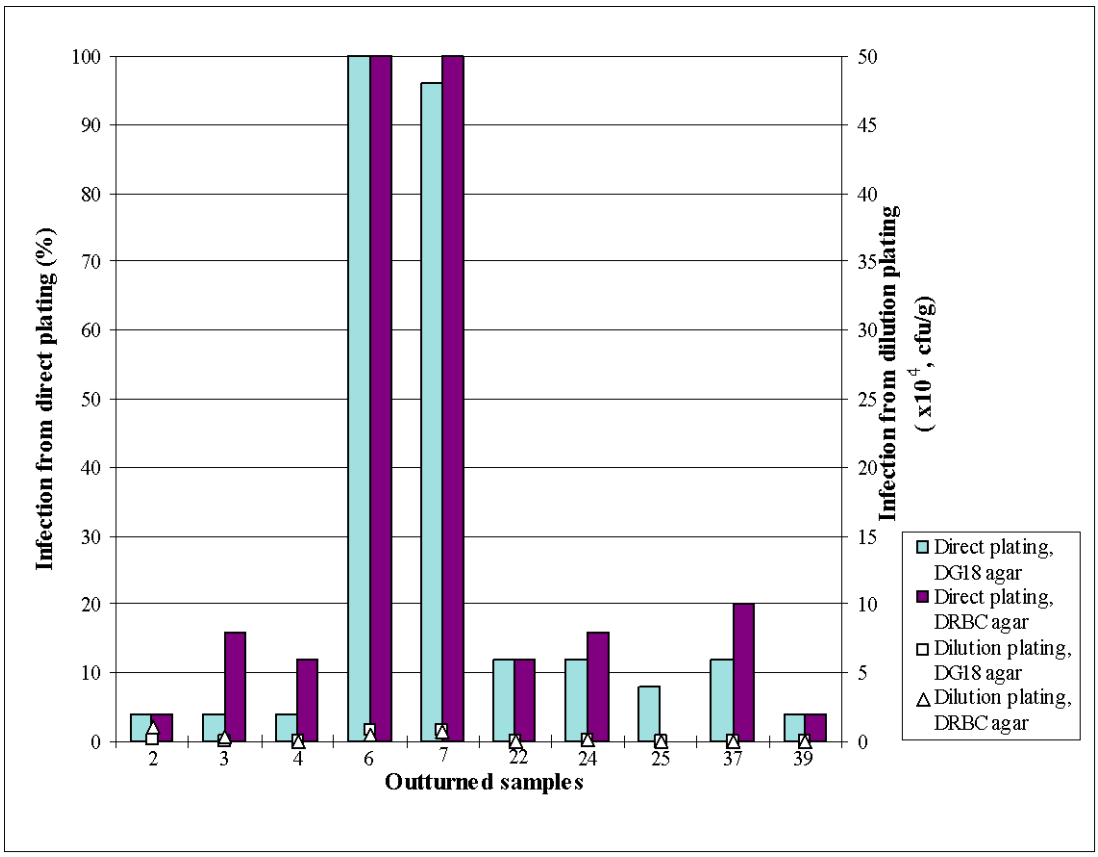


Figure 6. Calibration of moisture content determination for Dun type varieties of field peas using a Riceter moisture meter at Wallaroo grain terminal during the 1996/97 and 1997/98 harvest against a standardised oven dried method.

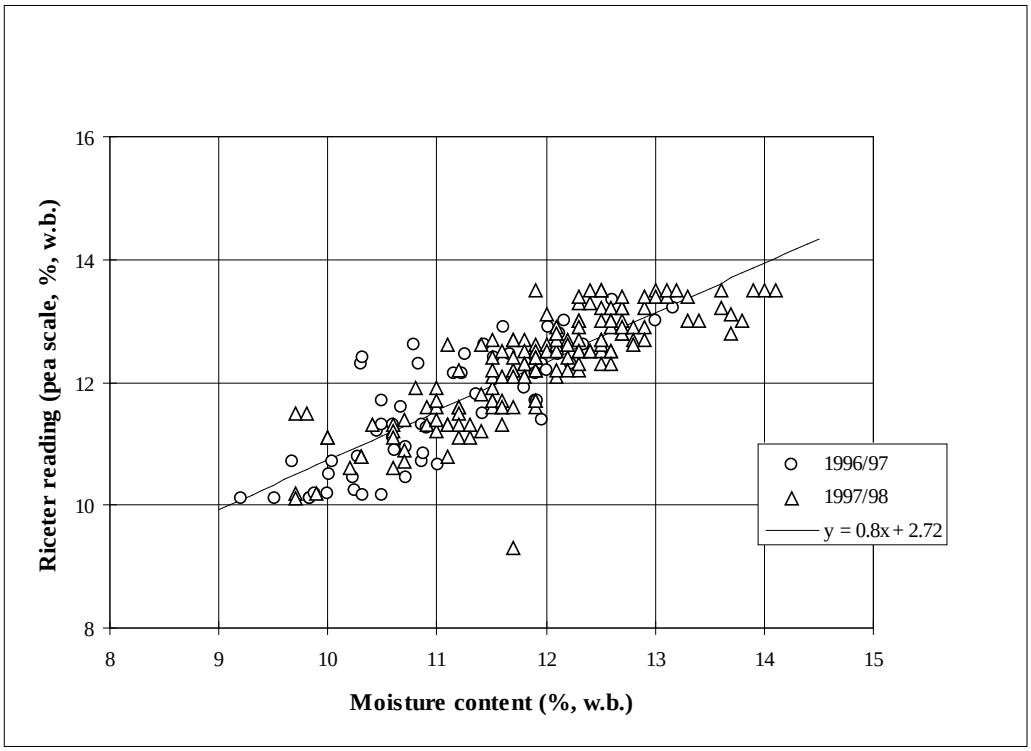
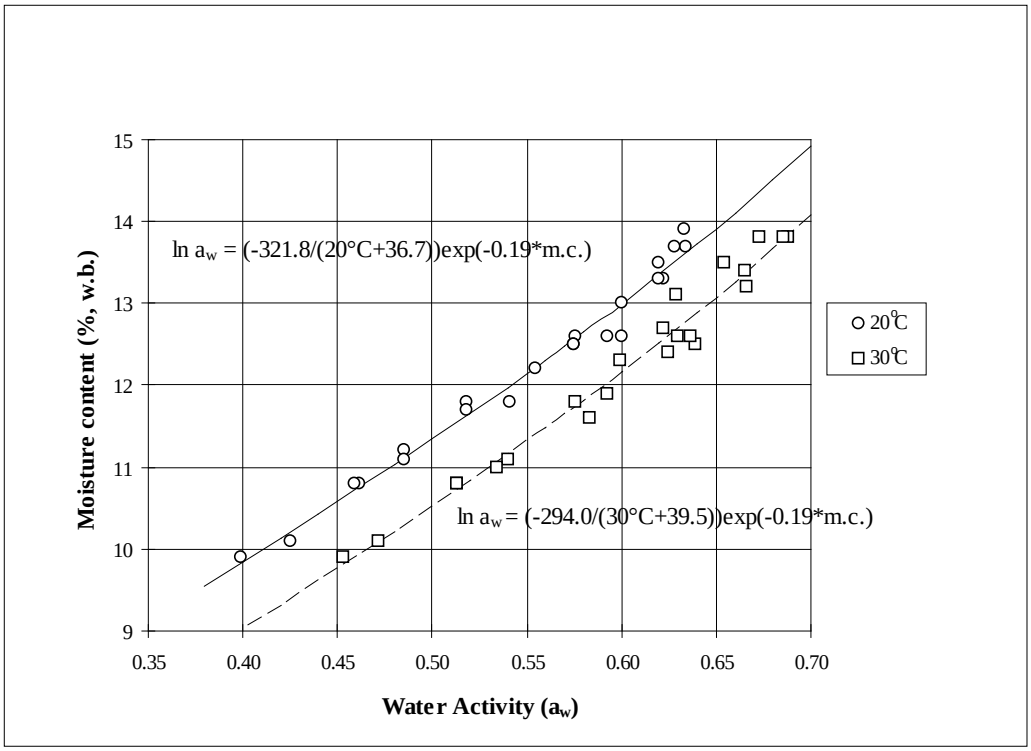


Figure 7. Moisture isotherms for Dun type field peas.

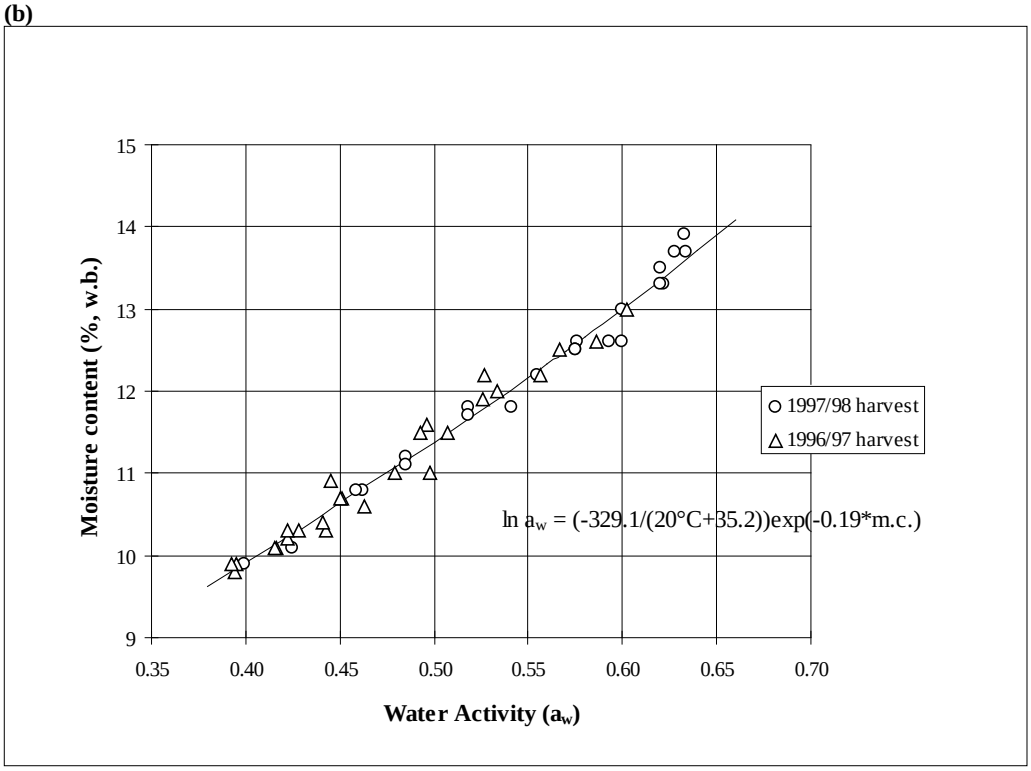
(a) 20°C and 30°C for field peas collected during the 1997/98 harvest.

(b) 20°C for field peas collected during the 1996/97 and 1997/98 harvest.

(a)


15
14
13
12
11
10
9
0.35
0.40
0.45
0.50
0.55
0.60
0.65
0.70
Moisture content (%, w.b.)
Water Activity (a_w)
ln a_w = (-321.8/(20°C+36.7))exp(-0.19*m.c.)
ln a_w = (-294.0/(30°C+39.5))exp(-0.19*m.c.)
20°C
30°C

(b)


15
14
13
12
11
10
9
0.35
0.40
0.45
0.50
0.55
0.60
0.65
0.70
Moisture content (%, w.b.)
Water Activity (a_w)
ln a_w = (-329.1/(20°C+35.2))exp(-0.19*m.c.)
1997/98 harvest
1996/97 harvest