Guidelines for Growing Hazelnuts in New Zealand

Bulletin 4: Nut Development and Quality

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Successful hazelnut production depends on producing high yields of nuts that meet the quality standards imposed by the market. An understanding of the stages in the development of the hazel nut can help growers understand the causes of many of the nut quality and production problems.

Nut development

Nut development starts with pollination of female flowers over winter. Hazelnut female flowers consist of pairs of stigmatic styles, usually red in colour, that emerge from the bud scales. Each flowering bud can contain between 4 and 16 individual flowers, each with the potential to grow into a nut if pollinated. Unlike most flowering plants, hazelnut flowers do not have an ovary and mature egg cells ready for fertilisation at flowering. Instead there is a tiny bit of tissue, called an ovarian meristem, at the baseof the stigmatic styles. If pollination with compatible pollen occurs, pollen tubes grow down to the base of the styles and enter a resting period.

Successful pollination stimulates the ovary to start developing from the ovarian meristem. After nearly four months of slow growth, the ovary grows rapidly within a developing shell and husk over 5 to 6 weeks. During this period the ovaries mature, the resting sperm becomes activated and fertilisation takes place. In New Zealand this is probably during late November and December in most regions. The shells are full size by mid to late December.

Kernels grow rapidly after fertilisation, taking about 6 weeks to reach full size. A further 6 to 8 weeks later, the nuts reach full maturity. At this point they can be easily dislodged from the husk.

The period from fertilisation to nut maturity is a critical time for nut quality. Anything that slows or stops the progress of the rapidly developing nut will have an impact on the quality of that nut.

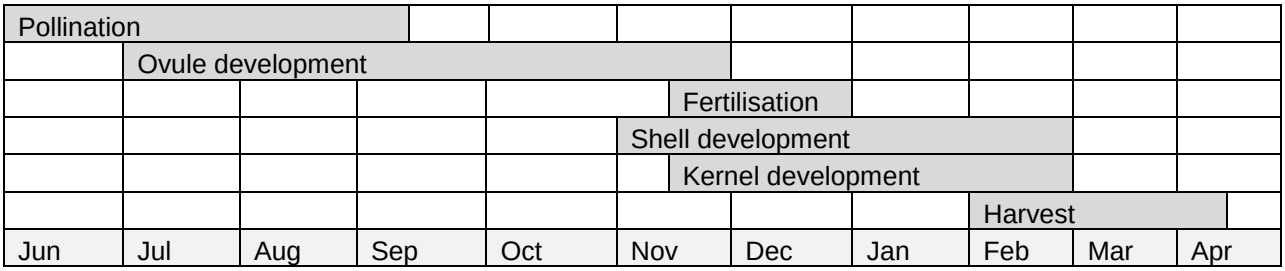

Fig. 1: Stages of nut development.

(The exact timing will vary with variety and location. Early flowering varieties develop earlier.Cooler southern regions may be four to six weeks later than northern locations.)

Quality

International quality standards

A number of quality standards exist for both in-shell hazelnuts and hazelnut kernels. Some producing countries and regions, such as Turkey and Oregon (USA) have quality standards for hazelnuts sold by their industries, and some countries have minimum standards for the importation of hazelnuts (e.g. USA). International standards have been set by the United Nations Economic Commission for Europe (UNECE, 2007 & 2010) and the OECD (OECD 2011). These standards are all similar. The OECD standard is the most recent and is likely to be the standard that New Zealand growers or processors will have to meet for exported nuts and kernels. The OECD standards, which include photographs illustrating faults and minimum requirements for these faults can be downloaded from http://www.oecd.org/tad/code/50300442.pdf.

These standards grade in-shell nuts and kernels into three grades, depending on the number of defects. These grades are: Extra Class, Class I and Class II, in order of increasing incidence of defects. Class II can be taken as the minimum quality required for exported nuts to meet international standards.

In-shell nuts

In-shell nuts must have intact, clean shells free from stains or blemishes affecting more than 25% of the shell surface. The kernels must be sufficiently developed (filling at least 50% of the shell cavity), not shrivelled, and free from mould or damage by pests. In-shell nuts should have a moisture content of less than 12% for the whole nut or 7% for the kernel. Most of the nuts (at least 90%) must be of the specified variety.

The OECD Class II standard allows a maximum of 20% defective in-shell hazelnuts for shell or kernel defects, with a maximum of 12% blanks or poorly filled, and 6% rancid, mouldy, rotting, or damaged by pests.

Large nuts are preferred by markets for in-shell nuts. Minimum size under the OECD standard is 12 mm in diameter. The standards adopted by the Hazelnut Growers of Australia (HGA) are typical of the size grades used by in-shell markets:

- Small: up to 13 mm
- Medium: 13.01 to 18 mm
- Large: 18.01 to 19.5 mm
- Very Large: 19.51 to 22 mm
- Jumbo: over 22 mm

The HGA standards do not allow mould or insect damage, allow just 5% blank nuts and specify a maximum 5% kernel moisture content.

Kernels

OECD requirements for hazelnut kernels are similar to those stated for the kernels of in-shell hazelnuts with additional provisions for the intactness of the kernel (loss of parts of the pellicle or kernel more than 3 mm in diameter and 1.5 mm in depth during cracking) and a lower moisture content requirement of no more than 6% moisture.

OECD Class II allows a maximum of 18% defective hazelnut kernels, of which no more than 8% are insufficiently developed (including shrivelled or shrunken), 2.5% mouldy, and 6% rancid, rotten, have an off odour or flavour, or are insect damaged. Maximum tolerance for damaged kernels and pieces greater than 5 mm is 10%; and 2% for pieces smaller than 5 mm. Not more than 8% can be twin kernels, or 10% kernels of varieties other than that specified.

These standards apply to nuts at the export or market control stage after preparation and packing. For growers, achieving acceptable nut quality at harvest depends on the ability of the post-harvest cleaning and processing systems to remove defective nuts. Blanks and poorly filled nuts, including badly shrivelled kernels, can be separated during cleaning or after drying, using air leg systems. Kernel defects are hidden until cracking so nuts for the in-shell trade need to have very few kernel defects.

For nuts that are cracked, defective kernels require removal by hand and a high incidence of defective kernels results in the processing line slowing or extra labour being required. These extra costs are likely to be passed on to the grower, or crops may be rejected.

Nut quality defects and factors influencing nut quality

Defective nuts include blanks (nuts with no or very small kernels within the shell), twins (two kernels in a shell), mouldy nuts, kernels with black tips (caused by a weak shell suture), poorly filled nuts, and shrivelled kernels.

The percentage of defective nuts is influenced by both genetics (some varieties are more susceptible to defects) and environmental conditions that promote expression of those defects. There are important varietal differences in the production of blanks and twins, and in susceptibility to mould.

The significance of nut quality defects depends on whether defective nuts can be effectively and economically removed from the crop before sale. Blanks and poorly filled nuts, plus nuts with very shrivelled kernels, can be separated mechanically from the well filled nuts during the cleaning or drying processes, usually using air leg systems after drying and sizing. Shell defects are removed by hand on sorting tables. Kernel defects are also removed by hand after cracking as they pass over sorting tables. Automated laser sorters that blow out shell and defects from cracked nuts are now available overseas.

Common nut quality problems

Blank nuts

Blanks are nuts where the shell is empty or has an undeveloped kernel filling less than 25% of the shell.

Blanks occur when pollination stimulates the shell to develop but the kernel fails to develop normally. Either fertilisation fails to occur or embryo development is stopped at an early stage, leaving a small undeveloped kernel. This may be caused by any of the main factors that place the tree under stress – low soil fertility, poor tree nutrition, adverse climatic conditions (such as drought or intense heat), lack of light in the canopy, or heavy crop load. Some varieties, such as Barcelona and Tonda Romana, produce more blanks than others. Cool temperatures during the time of fertilisation(Late November – December in NZ) have been suggested as one possible cause of blanks.

Blanks are not a problem when cracking for the kernel market but are unacceptable in nuts sold in-shell.

‘Brown Stain’

Brown stain is a disorder that causes distorted shells and leads to an increase in the incidence of blanks and poorly filled nuts. The name for the disorder describes the symptoms: brown liquid oozes from the shell of affected nuts in late December/ early January, staining the surface of the nut. The cause is unknown but it is suspected to be a physiological problem.

In severe cases the shell is distorted and the kernel destroyed. In less severe cases, the brown stained area of the shell has a pale, dull, sunken appearance. The shell is often softer in the affected area (Fig. 2).

Fig. 2: Barcelona nuts with shells distorted by Brownstain.

Shell defects

Shell defects are relevant only for nuts destined for the in-shell markets. These defects include damage by insects, scarring by bacterial blight, mould or stains making up more than 25% of the shell surface. The shell should be free of any soil residues or adhering husk. Nuts with shell defects are usually removed by hand after drying.

Insect damage to the shell surface is not common in New Zealand but caterpillars (species not identified) have been observed feeding between the husk and nut surface on developing nuts, causing distortion of the developing shell or marking of the shell surface.

Superficial shell cracks

Nuts of the Butler variety have a high incidence of superficial marks that form long pitted areas on the shell resembling short cracks but the marks do not penetrate through the shell (Fig. 3). The cause of these is unknown but they can affect a significant proportion of the nuts. The marks darken and become mouldy more rapidly than the rest of the shell surface.

Fig. 3: Superficial cracks on Butler nuts

Shell colour

Some nuts have a shell colour that is darker than normal, usually a greyish brown colour. These nuts are often empty or poorly filled. Very dark or black nuts are usually nuts from the previous season.

Shell stains

Localised discoloration of the shell is classed as a defect if it covers more than 25% of the surface area of the shell. It can be caused by sun scorch on short husked varieties like Ennis.

Blight scars

Bacterial blight can develop on the husks and infect the surface of the soft developing shell, resulting on slightly sunken greyish or dark brown lesions (Fig. 4). It is most common on varieties susceptible to bacterial blight such as Ennis and Barcelona. Blight scars are usually too small to be considered a defect under OECD standards.

Fig. 4: Scars caused by bacterial blight(Xanthomonas campestris pv. corylina)

Split sutures

Some varieties have weak sutures and hairline cracks develop along the sutures of some nuts (Fig. 5). When these split, the tips of the kernels can blacken and frequently become mouldy.

Split sutures are common in Barcelona and Tonda di Giffoni.

Fig. 5: Barcelona nuts with split sutures

External mould

Mould develops on the shell when nuts are left in damp conditions for too long after nut fall. This can occur while the nuts are on the ground or after harvest if they are not washed and dried immediately. It often starts on the apex of the nut, especially on those varieties with a downy shell surface such as Barcelona.

Fig. 6: External mould on Ennis hazelnuts.

Soil, silt or clay on the shell surface

Any soil or foreign material on the surface of the shell is a possible source of contamination. All nuts should be washed and the shell surface sterilised before drying.

Fig. 7: Fine silt contaminating the lower shell

Kernel Defects

Poorly filled nuts, shrunken and shrivelled kernels

Poorly filled nuts have kernels that fill more than 25% but less than 50% of the shell cavity. Shrunken nuts have sunken areas in the kernel. This has been attributed to rapid kernel growth in extremely high temperatures. Shrivelled kernels have wrinkling over more than 50% of the surface of the kernel.

Any environmental factor that stresses the trees during kernel development (January – February) increases the number of empty, poorly filled, shrunken and shrivelled nuts. These factors includelow soil fertility, poor tree nutrition, adverse climatic conditions (such as drought or intense heat), lack of light in the canopy, or heavy crop load. The proportion of poorly filled and shrivelled kernels is higher in varieties with large nuts such as Ennis than in varieties with smaller nuts such as Whiteheart. Bacterial blight has also been implicated in the incidence of shrivelled kernels. Blight scars can partially girdle the shoot supporting the nut cluster, disrupting the flow of photosynthates to the developing nuts.

Kernels with minor shrivelling or poor fill can be used for paste or oil provided the flesh is not tough and leathery.

Fig. 8: Poorly filled nuts

Fig. 9: Shrivelled kernels. The kernels above the line are suitable for paste or oil; those below the line are too shrivelled.

Twin kernels

Twin kernels are considered defects because the resulting individual kernels are usually below the minimum size for most kernel grades. Mould can sometimes develop in the gap between the two kernels.

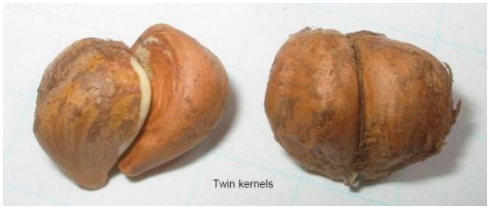

Fig. 10: Twin kernels (Barcelona)

Mould

Any visible growth of mould either on the outside or inside of the kernel is considered a defect (Fig. 11). Internal mould (on the surface of the internal cavity of the kernel) can only be detected by splitting the kernel. Mould is often associated with severely shrivelled kernels and the fungi may be secondary opportunists invading stressed kernels.

Fungal species associated with mould on hazelnuts include *Aspergillus* spp, *Penicillium* spp, *Cladosporium* spp, and *Phomopsis* spp. Overseas research has foundthat spores may be present throughout nut development but will not necessarily develop in the nut.*Aspergillus flavus* and *Aspergillus parasiticus*are known to produce aflatoxins and nuts contaminated with these moulds are unsuitable for human consumption.

The main influences on the incidence of mould are variety and climate, with significant differences in susceptibility of varieties to mould. Tonda di Giffoni frequently has mouldy kernels; Whiteheart seldom has problems with mould. Mould is highest after wet weather in the spring or during harvest. Warm humid conditions favour the growth of these moulds and growers need to ensure that nuts are not kept in damp conditions during the harvest and post-harvest period.

Control of mould through orchard management is difficult. Experiments using fungicide sprays in the spring, autumn and winter failed to reduce the incidence of mould in Oregon. Pruning to keep the canopy open may help to minimise mould development.

Black tips

Black tips are caused by necrosis of the kernel tip, sometimes with visible mould (Fig. 11). The necrosis extends a few millimetres into the kernel. Black tips are most common in varieties with weak sutures. Shells crack along the suture, allowing the entry of moisture and fungal spores.

Black tips are listed as kernel defects in cultivar trials but are not defined as a distinct class of defect in any of the international standards. The only OECD defect definition that would cover black tips is ‘kernel discoloration’.

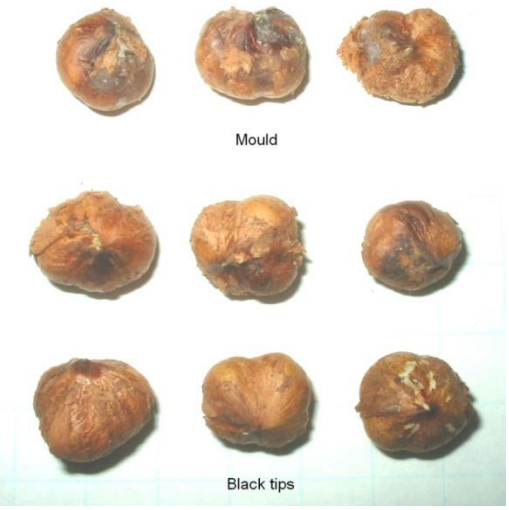

Fig. 11: Kernels affected by visible mould (top) and black tips (bottom two rows)

Kernel discoloration

The OECD standard states that kernels must be "free from blemishes, areas of discoloration or spread stains in pronounced contrast with the rest of the kernel affecting in aggregate more than 25% of the surface of the kernel". This is further defined as "apparent localized alterations of external or internal colour from any cause whatsoever…but excluding blemishes caused by a more serious defect such as mould, decay or damage by pests" (OECD, 2011). Any colour blemish that does not affect the edibility of the kernel is not classed as a defect. A taste test is recommended to decide whether or not edibility is affected.

Internal deterioration and rancid nuts

Some kernels deteriorate internally with no significant change to the appearance of the pellicle. The pellicle sometimes darkens and lifts from kernel beneath. This deterioration turns the kernel rancid; the colour of the kernel flesh turns yellow and waxy in appearance (Fig.12). This damage is often only evident after blanching and the frequency of this defect can only be determined by cutting a sample of kernels to check the kernel interior.

Fig. 12: Kernels showing internal deterioration. Some of this damage was not evident until the nuts were blanched.

Fibre

The absence of fibre on the kernel is desirable for nuts destined for the in-shell trade or kernels to be sold for use as raw kernels. The fibre gives a bitter taste to the kernel and detracts from the general appearance of the raw kernels. Fibre is not a concern for blanched or roasted nuts provided it can be completely removed with the pellicle. For varieties that do blanch well (e.g. Campanica, Nocchione), blanching of the kernel by lightly roasting nuts destined for the in-shell trade causes the fibre to fall away with the pellicle when the nuts are cracked.

Corky fibre acts as a sponge, holding moisture around the kernel and slowing the drying of the kernel. It can also impede the separation of the shell from the kernel after cracking if the fibre is adhering tightly to both the pellicle and the inner surface of the shell (Fig. 13).

Fig. 13: Shell adhering to fibre on a Barcelona nut

Insect damage

Hazelnut kernels can be damaged by green shield beetles (*Nezara viridula*). These feed on both developing and mature kernels. Damage depends on the time of attack. If the shell is still soft and the kernel is still developing, the kernel can be deformed and/or brown spots appear on the surface of the kernel. The kernel develops a disagreeable taste. If the attack occurs after the shell has hardened and the kernel is fully developed, then the damage may be limited to the development of white spots, sometimes with a pinhead sized black spot in the centre. These white areas darken when kernels are roasted. Damaged kernels become rancid more easily than normal kernels.

The damage is difficult to detect on raw kernels, especially those with a covering of fibre, unless the nut has become distorted or developed mould on the damaged site. Insect damage becomes evident once the kernels are blanched. OECD standards allow this sort of damage as long as the kernel flesh is not affected and the spot does not exceed 3 mm in diameter and 3 mm in depth.

Fig. 13: Damage caused by the green vegetable bug *Nezara viridula*

Further reading

OECD. 2011. International Standards for Fruit and Vegetables: Inshell Hazelnuts and Hazelnut Kernels. *International Standards for Fruit and Vegetables, OECD Publishing*.

http://dx.doi.org/10.1787/9789264166721-en-fr

Redpath, M.S. 2013. Assessing regional nut quality differences in New Zealand hazelnut varieties. *MPI Sustainable Farming Fund report L12-111. 49 p*

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All photographs: Murray Redpath

How to minimise nut quality problems in your hazelnut crop

Variety selection

Choose varieties that are adapted to your local climatic and soil conditions

- High yielding varieties with large nuts (Ennis, Butler, Lansing, Barcelona) require high quality soils (Class 1 or 2), excellent shelter, and ideal climatic conditions (adequate soil moisture, high sunshine hours, temperatures of 20 - 35˚C from late November to harvest)
- Varieties that are susceptible to black tip and mould (Lansing, most of the Italian varieties) require dry weather over late summer and harvest.
- Growers in locations with cool, damp climates should plant varieties with small to medium nuts that fall free from the husk at harvest. The kernels should ideally be free of fibre.
- Locations with less than ideal growing conditions (e.g. Class 3 soils, exposed to hot, dry winds, cool summer temperatures, very hot dry summer climate) should plant varieties with small to medium nuts such as Whiteheart, Tonda Romana or Tonda di Giffoni.

Orchard Management

Orchard management should aim to minimise stress on the tree during the main nut fill period from mid December to March.

- Use soil tests and leaf analysis to maintain optimum soil fertility.
- Ensure that soil moisture levels are adequate
- Keep trees well pruned to maintain adequate levels of light throughout the canopy.
- Keep the orchard floor clean and free of debris. Collect or mulch all debris and old nuts well before harvest.
- Maintain control programmes for rats and mice.

Harvest

- Do not leave nuts on the ground for more than one month after nut fall.
- Harvest more frequently if leaf fall occurs while the nuts are falling, if regular rainfall keeps the soil and nuts wet, or if many nuts are falling in husks (especially if husks are not completely dry).
- Wash nuts immediately and rinse in sterilizing solution (e.g. sodium hypochlorite). Scrubbing may be necessary if shells are coated with silt or clay.
- Dry immediately. For small scale growers, nuts can be dried in shallow layers on racks (stir frequently) to a minimum of 10-12% moisture before bagging in onion bags for final drying to 6% moisture. Forced air drying systems should not use temperatures over 35˚C.
- Store in a dry cool room (air humidity less than 65%, temperature less than 20˚C) free of any other product that may contaminate the nuts. Hazelnuts will absorb odours if other strong smelling products are stored in the same room.