FODDER OATS: AN OVERVIEW

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Oats in a global context

Growing and production trends

Oats rank around sixth in the world cereal production statistics following wheat, maize rice, barley and sorghum. Oat grain has always been an important form of livestock feed. They are a good source of protein, fibre, and minerals but world oat grain declined as farm mechanisation increased between 1930 to 1950. Oats remain an important grain crop for people in marginal ecologies throughout the developing world, and in developed economies for specialist uses. In many parts of the world oats are grown for use as grain as well as for forage and fodder, straw for bedding, hay, haylage, silage and chaff. Livestock grain feed is still the primary use of oat crops, accounting for an average of around 74% of the world's total usage in 1991 to 1992 (Welch 1995).

Oats are better adapted to variable soil types and can perform better on acid soils than other small grain cereals crops. They are mostly grown in cool moist climates and they can be sensitive to hot, dry weather from head emergence through to maturity. For these reasons, world oat production is generally concentrated between latitudes 35 – 65°N, including Finland and Norway, and 20 to 46°S.

Most of the world's production comes from spring sown cultivars, but autumn sowing is practised along the higher altitude regions, including the Himalayan Hindu Kush range and in regions where summers are hot and dry. Where winters are severe, such as in Scandinavia, northern states of the US, Canada, and higher altitude regions in the tropics, short season to mid maturing oat cultivars are generally sown.

In regions with temperate climates, oats are variously spring, winter and/or autumn sown depending on regional climatic conditions, crop rotation requirements, end use and other farming practices. In warmer regions, spring type oats can are sown in autumn to avoid summer heat and drought.

Russia, countries of the former Soviet Union, the US, Canada, Germany and Poland account for about 75% of the worlds supply of grain oats, seed and industrial grade oats. Since the 1960s the proportion of oats used for feed has declined in the US and Canada, remained unchanged in the former Soviet Union countries and Poland, and increased slightly in Germany.

Oats consumed as feed in the US are becoming a specialty feed for race horses, hobby farmers and breeding stock. The leading exporters of oat grain are Canada, Finland, Sweden Australia, and Argentina. The US, Japan, the former Soviet Union, Switzerland and the European Union are the principal importers of oat grains.

A significant proportion of the oat grains and forages produced on smaller more remote farms around the world, including in the Himalayan region, are consumed on the farm and never enter the commercial market place. A case study from Nepal (Stevens et al. 2000) covering oats dating back to the 1950s, shows how people in Pakistan, Afghanistan and China could benefit substantially from access to better performing cultivars to alleviate poverty and improve human and animal nutrition. These examples highlight the need for a co-ordinated international fodder oat network targeting resource-poor environments in the relatively remote communities.

Oats are grown for use as grain as well as forage and fodder, straw for bedding, hay, haylage, silage and chaff. Food uses for oats include oatmeal, oat flour, oat ban and oat flakes for use as breakfast cereals and ingredients in other food stuffs. Oats are one of the most nutritious grain cereals, high in protein and fibre. The protein of rolled (flakes) oats is generally greater than that found in other cereal grains. Many of the vitamins and minerals found in oats are combined in the bran and germ. Most oat food products use the entire groat, making it a nutritious cereal grain.

Adaptation of *Avena* species

The exact origin of the oat is unclear. Oat (*Avena sativa*) seeds have been found in 4000-year-old remains in Egypt. Oats may have spread there as a weed in wheat and barley crops. Oat cultivation began much later than that of wheat and barley. Oats descended from a number of diploid (14 chromosomes) and tetraploid wild species. These grew mainly in the countries around the Mediterranean Sea, whereas the primitive wheats were grown mainly around South West Asia.

Oats were grown for grain in western Europe and mention was made of a red oat grown for fodder around Asia Minor.

The European white oat, or yellow hulled oat, is thought to be the progenator of the common oat, *Avena sativa*. It spread to all parts of the world where moist cool conditions prevailed, and was used as spring sown crops for food and feed grains. The wild red oat, *A. sterilis*, is thought to have been the progenator of the cultivated red oat, *A. byzantina*. This species spread to the regions where temperature extremes occur frequently such as the Mediterranean, southern states of America, Africa, South America and Australia, and was used mainly for forage production. The *A. byzantina* species generally has greater heat, drought and cold tolerances. Both species are hexaploids with 42 chromosomes.

Fodder oat improvement

The European white oat or yellow hulled oat, *A. sativa*, and the cultivated red oat, *A. byzantina*, are self pollinating hexaploids and compatible with hybridising techniques.

In recent times, plant breeders have hybridised these species to select mainly grain and food type cultivars that are adapted to a wider range of climatic conditions.

Most plant breeding investment has and still is directed toward the improvement of grain production for food uses, where white grain types are generally preferred. Consequently, the colour of grain of both species is becoming more like that of *A. sativa* and less like that of *A. byzantina*.

According to Coffman (1977) in Argentina where *A. byzantina* was formerly the most popular species, *A. sativa* types now predominate. In the US most of the spring oats are *A. sativa* whereas the winter oats in the southeast and southwest originated as *A. byzantina*. Through the development of improved cultivars *A. byzantina* has become more like *A.sativa* in appearance.

Modern plant breeding/oat development focused primarily on oats grown for grain production, not fodder production. This development and investment bias toward grain cultivars is continuing with few exceptions, resulting in very few specific global references in the literature to fodder oats.

There are major monographs (Webster 1986; Marshall & Sorrells 1992; Welch 1995) on grain oats but there are few literature sources useful for fodder oat improvement even though fodder oats are used as a multi purpose crop worldwide. They are usually autumn sown, grazed prior to stem elongation and taken to maturity for use as feed and/or milling grains. Traditional oats (*A. sativa*) are used for forage purposes throughout the world.

A diploid oat species (*A. strigosa*) is also grown in South America as a forage crop. Sullivan et al. (1982) compared a diploid oat with a triticale forage for fattening cattle. Although the diploid oat had a lower nutritive value the oat yielded more forage per hectare than triticale.

Research reviewed by Burgess et al. (1972) found the nutritive value of oat forage is high and showed to have dry matter digestibilities in excess of 75% when fed to dairy cattle.

Cuddeford (1995) suggests cereal straws have similar chemical compositions but oat straw has higher digestible organic matter content. He suggests that straw from spring oats has a higher metabolizable energy (ME) content than winter oats and both are better than the other cereals in terms of available energy. Oat straw is softer and more acceptable to livestock than other cereal straws.

Despite the extensive worldwide use of oats for forage and fodder uses, very little of the world's research plant improvement resources are devoted to the development of the oat crop specifically for fodder uses, consequently little detailed research data is available for review documents such as this paper.

Breeding and selecting for both seedling and adult resistance to crown rust in particular is an important part of oat improvement programmes in many of the world's oat grain producing areas. In Brazil, where oat crops are widely grown for forage, serious problem with crown rust exists. A similar situation exists in Queensland Australia and in New Zealand, where the increasing production of oat forage has increased the incidence of fungal diseases in oat crops such as crown and stem rust.

Therefore, it is not surprising that cultivars selected for grain crops, in environments where plant diseases are potential yield limiting factors in crop production, have in many cases fulfilled the requirements for improvements in forage yields. Many of the plant traits required for successful crop production apply to both forage and grain outcomes.

All cultivars in New Zealand and Australia are spring types, some with winter cold tolerance resistance.

'Winter oats', not to be confused with 'winter hardiness', is frequently used in a generic sense, for example spring oats planted in the winter. Winter hardy oats may have a place in the higher cooler reaches of the Himalayan ranges, but it could be difficult to identify winter hardy types specifically for the TAPAFON trialing network. Breeding and selecting for improved winter hardiness is difficult. The trait is genetically complex and field selection is difficult in most environments as it is either too warm or excessively cold for effective selection. Laboratory methods can be used but these are expensive, and not precise. Despite these difficulties progress, intentional or otherwise, has been made in developing oat germplasm with greater winter hardiness.

Marshall et al. (1992) in his review of winter hardiness, demonstrated that the area of winter oat adaptation in the US showed a northward movement between the 1920s and 1960s due to the development of cultivars with improved winter hardiness.

For Himalayan region it is important oats are screened for cool tolerance by sowing, at high altitudes using susceptible and known winter hardy cultivars as controls, and using vegetative survival as the criterion for selection.

In the early stages of a plant improvement programme accessing germplasm for parental uses is crucial to the success of plant improvement programmes. Several countries or their institutes, including individual plant breeders, maintain germplasm collections. Wesenburg et al. (1992) estimates that there are at least 22 significant *Avena* collections in the world, containing around 37 000 accessions.

By comparison, there are 37 significant wheat collections of 401 500 accessions and 51 barley collections of 212 000 accessions. A list of *Avena* germplasm base collections is published in Oat Science and Technology: (1992) pages 799 to 803. The US Department of Agriculture, Agriculture National Small Grains Collection (USDA-ARS NSGC) is a collection made up of more than 113 000 accessions of wheat, barley, oat, rice, rye and triticale and a comprehensive collection of wild and cultivated species. It is maintained at several sites.

The NSGC germplasm is relatively easy to access through the internet, or by mail. But this material, unless its field performance is already known, is best screened within established programmes. Accessing and evaluating germplasm can be a costly business and best done, in the first instance, inside established programmes linked to the TAPAFON network.

Cultivar development involves the selection of parents, hybridisation among parents, inbreeding and selection among the resulting progeny, replicated testing for yield and other important quantitative traits and finally multiplication, maintenance and distribution of seed. The cultivar improvement objectives will reflect the producer needs in the target environment region, and the end uses of the crop, such as grain, straw or fodder. Successful plant improvement programmes are difficult and expensive to replicate, within a short timeframe. Therefore, successfully networking with the Himalayan communities, site controllers and researchers is the obvious recipe for the Temperate Asia Pasture and Fodder Network (TAPAFON) to successfully accomplish its mission.

Genotype by environment interactions

Traditionally, discarded oat cultivars developed for grain production have and still are used for forage and fodder uses worldwide. Screening for forage and fodder production uses has evolved using grain types, because they may not have met the target grain yields, but are observed to have potential forage capability so consequently are streamed for potential forage uses by researchers whose primary focus is on improving grain yield.

For example, dual purpose cultivars selected from Canadian and European stocks for New Zealand continued to be used up until the late 1980s when the first cultivar (Charisma) selected entirely for forage use was released by Crop and Food Research (CFR). Until this time Mapua 70, a reselection from Makuru, developed from UK cultivar Milford was the major forage and milling oat used in New Zealand. A discarded grain cultivar (Lordship) from the New Zealand oat programme was released in Australia as a forage oat, although it is currently used for hay production. An unreleased CFR cultivar with good grain yield is a potential candidate for release as a forage oat in New Zealand. It has also performed well in forage trials in the US states west of the Rocky Mountains, and has been included in lines from New Zealand to be tested in the Himalayas.

According to Stevens (2000), oats originating from Canada, Europe and New Zealand and introduced into Asia over the past 20 years continue to play a highly significant and strategically important role in feeding livestock across a wide range of ecologies, especially within the poorer regions of countries bordering the Himalayas, where they are used either as green feed or oaten hay.

Considerable genotype by environment interaction has been noted across latitude, altitude and seasonal sequences, with some cultivars producing significantly better than others in certain regions and under certain management regimes. More recently bred cultivars and previously discarded populations never tested in these areas may have an important role to play in humanitarian relief, poverty alleviation and development throughout the developing world. This is, provided, these populations or cultivars can be properly introduced and systematically evaluated, tested, maintained and seed distributed. A similar situation applies to legume, arable, and tree crops.

Potential for oats in the HHK region

Fodder oats, mainly *Avena sativa*, have since the 1950s and 1960s grown to become a major forage and fodder crop along the Himalayan Hindu Kush (HHK) range from Afghanistan to Myanmar. Increasingly, cereal fodder crops are being used to encourage and facilitate moves toward zero grazing and tethered animals to spell over-grazed land at all altitudes.

The HHK range is characterised by steep topography, and climatic extremes such as very cold and prolonged winters at higher altitudes, variable soil types, and lack of irrigation in dry regions limiting the choice of agricultural activities. These constraints limit arable agriculture to around 3000 m above sea level.

Animal rearing is an important occupation in this region over all altitudes. At higher altitudes, above 3000 m, overgrazing by animals is a major problem throughout most of the region. In some areas it has resulted in the destruction of the natural vegetation and forest cover.

Alternative forage/fodder sources are needed, particularly those which encourage and can sustain a shift from free grazing to zero grazing/tethered grazing, and cut and carry systems. The forage/fodder sources should be preferably linked with a shift from lower value animals such as cattle, sheep and goats to buffalo. Buffalo can provide milk, meat and are useful draught animals for cultivating land

Remedial action is underway in a few areas, for example in Pakistan (AKRSP programme) and Nepal, where it has become clear that widespread nationally co-ordinated attempts to resolve the ecological consequences of overgrazing will require a considerable improvement in the productive capability of land currently used for arable purposes. This will sustain the current animal population and provide measurable material benefits to the communities living in these higher altitude zones.

To achieve this, traditional oat cultivars may need to be up-dated with winter hardy types for use in the higher altitudinal zones. New cultivars are needed to extend the existing range of cultivar options available to communities at the higher altitude levels along the HKK.

Cultivars with an improved yield capability that can be also grown at higher than the current climatic limits for arable agriculture could relieve some of the overgrazing pressures and destruction of the forestry. However a mix of arable and tree forage crops for feeding livestock at the high altitude sites also may provide alternative and more reliable options for livestock farmers.

Fodder oats are currently used along the HHK region for grazing feeding and bedding milking animals, young stock and draft animals. Some farmers use a cut and carry system which are very effective in conserving animal food, by reducing waste normally associated with direct grazing systems.

By using cut and carry systems farmers have greater management control over harvest timing, cutting height and consequently the vegetative recovery capability of the oat crop. The system also enable farmers to use overlapping cropping methods to provide a continuous supply of green feed for livestock.

Oat crops generally are more suited to cut and carry systems than direct grazing, particularly in cold environments. Cereal crops, unlike grasses, and oats in particular, have not been extensively bred for direct grazing situations, but despite this, direct grazing of cereal crops including oats is practised and can work well in warmer regions.

As the available land currently used for food production becomes scarce in relation to increasing population pressures, and the need for higher food production increases, greater research is needed to develop special purpose cultivars that fit specific end uses. There are few oat breeding programmes where the primary objective is developing oat cultivars for forage uses and very little work is underway to develop germplasm for conditions experienced in the cool and high altitude regions such as that found in the parts of the Himalayas.

The point at issue is to consider the potential for quantum leaps in oat cultivar performance if the oat crop was an International Agriculture Research Centre (e.g. ICARDA CIMMYT) mandated food crop. It would provide potential spin offs for smaller oat breeding operators to develop germplasm specifically for grain, forage and fodder uses, including the lowering of the temperature threshold at which oat germplasm can grow, and produce high yields of forage/fodder for livestock uses in cool regions including the HHK region.

Despite international funding issues, local crop improvement programmes have historically made the best possible use of whatever materials are locally available. There have been augmented by introduced genetic material from outside the region, bred in the overlapping ecologies of Europe, North America, Canada, Australia and New Zealand, and circulated via the Quaker oat nursery, the UN-FAO and a number of bilateral aid programmes.

Sadly, there has not so far been a coordinated international crop improvement programme for oats/fodder oats, as there has been with wheat, maize, rice and sorghum for example – leaving networks such as TAPAFON to look after there own needs

With the advent of plant variety rights combined with a down turn in international aid, it has become increasingly difficult for smaller less well off developing countries along the HKK to directly obtain and exchange germplasm and to otherwise access, evaluate, develop, maintain and produce seed of improved purpose-bred fodder oats for stress-prone environments.

This has occurred at a time when, more than ever, improved cultivars of fodder oats are needed to help alleviate poverty, restore and manage the environment in sustainable ways which enhance local seed and food security. New alternative networking approaches are needed, along the lines introduced and discussed in this paper.

The Himalayan region’s growers need access to modern cultivars without the imposition of business and compliance/administration costs associated with plant patent protection and seed distribution schemes in the countries in which these cultivars are developed

To achieve access to this new germplasm and cultivars the TAPAFON network should identify plant improvement groups willing to supply material and prepared to forgo seed royalties. This would mean substantial cost savings for the organisers, in a community based evaluation system where plant variety protection and royalty collection systems are not village based issues. The outcome would provide a rapid route to market for new cultivars. This would enable growers to take immediate advantage of new cultivars and technologies free from all business compliance and cultivar ownership issues, in the initial stages.

But the mechanisms for the funding of crop improvement projects, inside existing programmes, will need to be investigated by international aid agencies, governments. Businesses sponsorships could be investigated. Despite the problems associated with distributing modern oat cultivars and PVP and ownership issues, a wide range of oat germplasm is available to a network of plant breeders, who respect the conventions of germplasm exchange and access, for developing new populations. Released cultivars are usually maintained by the originating owner or their agent and could be available for germplasm enhancement projects if not for commercial use.

Summary

The potential for an Oat Fodder Network as presented by Stevens (2000) is generally accepted by oat research workers as the basis for moving forward to exploit the potential of the crop for the Himalayan region.

Realistically a structure such as an Oat Fodder network is required to actively access and screen this material prior to committing unknown, material directly into the trialing network without preliminary screening.

The Oat Network should also aim to develop a low cost preliminary screening system for a larger number of oat lines in the HHK region from which selections can be made for entry into the more formalised trialing system.

Alternative crops

Hull-less oat (Naked) is a variant of *A.sativa*, the cultivated hexaploid, traditional, grain and fodder oat, but without a hull. Naked oat cultivars offer farming families in this region a dual purpose cropping option, fodder and an alternative human food source. Naked oats are hull-less grains, where the caryopsis (groat) separates from surrounding plant tissue during the threshing process.

Hull-less grains could be milled into flour by local householders. However, oat grains (hulled and hull-less) also have a higher oil content compared to other cereal grains such as wheat, consequently the shelf life for oat flour may be shorter than wheat flour. Rancidity in damaged oat grains or milled flour can occur affecting taste, but is not considered of any consequence for animal feeding. Several countries are developing naked oats for use as a food crop.

Diploid (*Avena strigosa*) oat cultivars are another fodder crop option for use in the Himalayan Region. More suited to forage production than grain production, a diploid cultivar in New Zealand field trials produced high yields of vegetative fodder in winter forage trials, from autumn sowing.

Diploids are widely grown in South America for forage uses. The grain contains a husk, but naked varieties are available. No references for potential use as a food for milling into flour has been found at time of writing. In a recent glasshouse experiment at Crop & Food Research, the diploid cultivar was observed to produced a much larger root mass than traditional oat cultivars. This was not a controlled experiment for measuring root mass, but the differences between the diploid and a traditional hexaploid oat root mass on this occasion were large.

If diploid cultivars produce greater root mass under field conditions, diploids may have additional benefits in erosion control, in addition to fodder or hay uses. But the authors emphasise no research references have been identified to verify this observation.

Hull-less barley is a variant of hulled barley (*Hordeum vulgare*). Barley cultivars are generally early maturing and spring types can be reasonable cold tolerant, but winter types are less cold tolerant than wheat, rye and triticale, nevertheless barley does best on well drained fertile soils. From spring sowings selected short season cultivars could be used to produce, rapidly, high yields of fodder, or hull-less grains for household milling.

The potential of hull-less barleys has yet to be fully exploited. Selected hull-less barleys could have a place as a spring sown short season crop in high altitude environments for fodder and grain production.

Triticale is a cool-season annual small grain cereal. For food uses wheat is likely to be the more useful. Most triticale is grown for animal feed and fodder and only a little for human consumption, consequently the development of triticale types are currently been targeted for dual purpose forage and feed grain uses and multi grazing capability.

Rye (*Secale cereale*) sometimes as ryecorn to avoid confusion with ryegrass. Rye is a cross pollinated plant and grain yields can be affected by the weather at time of pollination. Rye production has fallen world wide but still widely grown in the former USSA countries and Poland where it is an important bread cereal. Rye is also used for forage. It is a hardy cereal and can be grown where winter conditions are too severe for wheat. Like oats it can be grown on a wide range of soils types. Its grain yields are poor and the seed ripens unevenly.

For forage use initial growth is slower than other cereals but rye can be grazed repeatedly and recover well even under hash conditions. In extreme conditions it may out yield other cereal crops.

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